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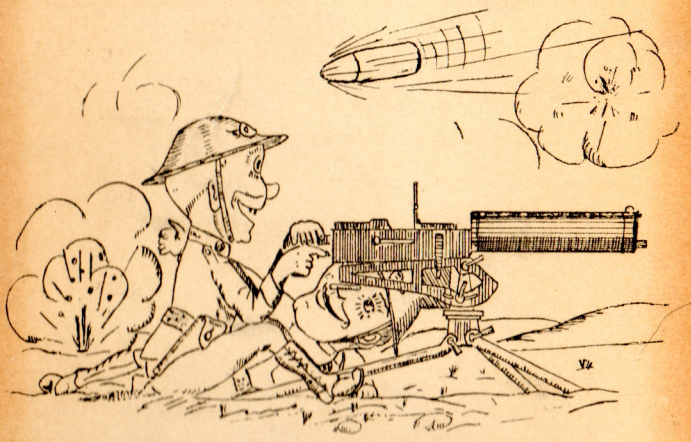
THE MACHINE GUNNER'S HAND BOOK



"PEP" AND "SNAP"
Machine Gun Twins

THIRTEENTH DIVISION
U. S. ARMY

Sgt. Jim Staats
Ordnance Dept. - Reference Copy
Aberdeen Proving Grounds

THE MACHINE GUNNER'S POCKET BOOK

Compiled by the

Divisional Infantry School of Arms
Machine Gun Department

Thirteenth Division
United States Army

For Machine Gun Officers
of the Division

Property of Ulrich R. Zuehlke

Co. A. 38th Machine Gun Battalion.

M. G.

Pub. 1918
Ft. Lewis, WA

Section "A"

FIRE DIRECTION

CONTENTS

DEFINITIONS

Fire Direction: The selection and application of the best method of engaging the target in conformity with the tactical situation. (For the proper use of fire direction one must know the size of shot groups, trajectory, size of cone, ordnance, etc., considered at different ranges.)

Trajectory: The path of the bullet during its flight thru the air. It consists of three branches, (1) rising, (2) summit, and (3) falling.

Line of Aim: Collimation of the front and rear sights prolonged.

Line of Sight: Imaginary line connecting target and axis of bore, at the muzzle. (English: Line from gun to target, and is straight.)

Line of Departure: Is the prolongation of the axis of the bore at the instant the bullet leaves the barrel.

Angle of Elevation or Angle of Departure: The vertical angle between the line of sight and the line of the axis of the bore, or the angle between the line of sight and line of departure.

Angle of Quadrant Elevation: The vertical angle between the axis of the bore and horizontal plane passing thru the bore at the muzzle.

Angle of Sight: Vertical angle between the line of sight and horizontal plane passing thru the bore at the muzzle.

Angle of Fall: Vertical angle subtended between the line of sight and line tangent to the trajectory at point of fall.

Initial Velocity: The rate of speed of the bullet the instant it leaves the muzzle.

Drift: The departure of bullet from plane of fire caused by rifling in barrel, and is to the right. It is corrected for in the rear sight.

Ordinates: The vertical distance between line of sight and trajectory at any given point.

Cone of Dispersion: The figure formed in space by the trajectories considered together of a series of shots fired at a single aiming point with one rear sight setting.

Beaten Zone: The intersection of the cone of dispersion with the surface on which the object of fire stands, or the pattern formed by the strike of the bullets in a series of shots with the same aiming point and same sight setting.

Effective Beaten Zone: That part of the beaten zone containing 75% of shots around the target, or pattern formed by joining the outside shots of the best 75% bullets.

Mil: An angle whose tangent subtends one one-thousandth of the range, i. e., one mil covers one yard of target at one thousand yards.

Quadrant Angle: Obtained by adding the angle of departure and angle of sight. (Algebraic sum of angle of departure and angle of sight.)

Angle of Sight: Above the horizontal is plus and below is minus, therefore for the quadrant angle we use the algebraic sum of the angle of sight and angle of departure.

Indirect Fire

1. Indirect Fire is that in which the aiming mark is not on the target. Direction and elevation may be obtained, put on, and maintained by the methods in the following table. In many cases two or more alternative methods are open to employment. That most suitable under the circumstances should be chosen.

Fire may be indirect by reason of:

1. Darkness, smoke or gas cloud, rain or fog, etc.
2. Some natural or artificial obstruction intervening between gun and target.

Note: In the latter case, it is necessary to determine whether the shots will clear the obstruction.

Indirect fire may be either observed or unobserved. If observed, its value is much increased, and fire may be directed on to the target with rapidity and confidence. When unobserved, the object of indirect fire should be to sweep a line, or area, which includes the target, or it may be used to form flank, frontal or oblique barrages.

When laying the gun for indirect fire, direction should always be put on before elevation. The importance of rigidity and immobility in the mounting and platform should always be borne in mind.

The following table shows in summarized form the various methods adopted to carry out indirect fire.

	DIRECTION.	ELEVATION.
How Obtained	Posts alone. Map-Protractor and Magnetic Bearing. Map-Protractor and Reference Object. Compass Bearing.	Graticules. Map Contours. Angle of Site Instrument.
How Put On.	Posts alone. Posts and compass. Reference object and Direction Dial. Compass in front or rear of guns.	Clinometer. Spirit Level and Rear Sight.
How Maintained.	A. A. M. Direction Dial.	Rear Sight and A. A. M. Clinometer.

2. Indirect fire will be dealt with under the following headings:

I. Without the map (i. e., where a 1-20,000 or larger scale contoured map is not available).
   (a) By graticules.
   (b) By angle of site instrument.

II. With the map (i. e., where a 1-20,000 or larger contoured map is available).
   (a) To obtain direction.
   (b) To obtain elevation.
III. Maintaining laying.
IV. Clearances.
V. Night firing.
VI. Searching reverse slopes.
VII. Errors.

Indirect Fire of Guns Controlled Singly.

I. Indirect fire without the map.
   (a) By use of graticules.

The following instruments are required:

(I) A range finder.
(II) Field glasses in which graticules are cut across the focal plane, or graticule cards.

Procedure:

(I) Move to a position from which the target can be observed. (This should not be more than about 6 feet above the gun, and at approximately the same range from the target.)

(II) Obtain range to target.

(III) Select a suitable aiming target, visible to the gun, which is vertically above or below the target, and in alignment with gun and target.

(IV) Using the graticule, align the correct range on the target.

(V) Note which graticule cuts the aiming mark, and the corresponding range.

(VI) Order the No. 1 of the gun to put this range on his sight and lay on the aiming mark.

As the range on the sight is not the range to the target, the fire cannot be corrected by ordering "up 50" or "down 50", etc. Corrections must therefore be applied by directing:

(A) The gunner to altar elevation by "turns" (i. e., the two mil alteration of the elevation wheel).

(B) Altering by ordering so many "mils up" or "down", the gunner reading this change on his elevating dial.

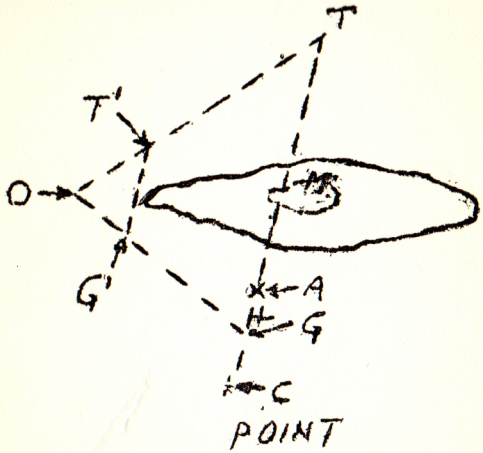
The following table gives the **approximate** number of "turns" required for each 100 meters increase or decrease in range:

0 — 900 meters = 1 turn.
1000 — 1400 meters = 2 turns.
1500 — 1900 meters = 3 turns.
2000 — 2300 meters = 4 turns.

Where a suitable auxiliary aiming mark can be seen above or below the target, this method is useful to bring fire to bear on a target which is visible through glasses, and is difficult to indicate to the No. 1.

(b) By a ground map.

The figure shows the gun position, G; target position, T; observation station, O.



The following instruments are required:

1. Range finder.
2. Angle of site instrument.
3. Compass.

Procedure:

To obtain direction: After selecting the gun position the controlling officer goes to a position from which he can see both the gun and the target, and—

(1) Takes ranges to the gun and to the target with the range finder.

(2) Measures the angle of site from O to T and from O to G.

This is done as follows:

With a convenient scale, e. g., 1 meter = 100 meters, lay off along the lines OT and OG′ the distances OT′ and OG′, representing the ranges OT and OG, respectively. Measure G′T′ and, using the scale, determine the range GT.

From G′take the bearing of T′. Since G′T′ and GT are parallel this is the bearing of the target from the gun position.

Having the angle of site from O to T, from O to G, and the distances OT and OG, the vertical intervals between O and T, O andG can be readily determined by the formula—

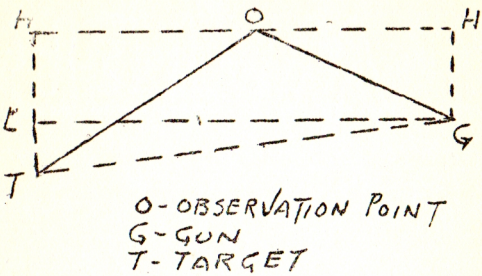
$$\text{V. I.} = \frac{\text{H. E. x Angle of Site}}{1000}$$

The V. I. between G and T is then readily determined (i. e., the difference between them found), and from this V. I. the angle of site from G to T obtained by the formula—

$$\text{Angle of Site} = \frac{\text{V. I. x 1000}}{\text{H. E.}}$$

From the range GT and the Angle of site, determine the Q. E. All necessary data to lay the gun on T is now at hand.

Where the observation post is in the direct line from the gun to the target, direction can be obtained by placing posts, and elevation as follows: (HOT—HOG Formula.)



O = Observation post.
G = Gun.
T = Target.
OT = Range from O to target.
OG = Range from O to gun.
GT = OT + OG (approximately and for all practical purposes).
HOT = Angle of site from O to T.
HOG = Angle of site from O to G.

Then, angle of site from gun to target

$$\frac{(HOT \times OT) - (H'OG \times OG)}{OT + OG} = \text{Angle LGT.}$$

In the use of this formula care must be taken to give the angles their correct signs.

The vertical intervals H'G, HT and LT can be readily determined as in the preceding case (LT = HT — H'G).

How to obtain direction by posts alone: The gun position, having been approximately selected, two of the guns' personnel advance with posts, until the target is visible. Two posts are then planted in such a manner that the target and these two posts lie on the same straight line, and the prolongation of this line passes through or near the gun position. If these posts are not visible to the firer, a third is driven in still nearer to the gun and in exact alignment with the other two; the procedure is repeated, if necessary, until two posts are visible to the firer, who will move his gun into alignment in case it is not there.

If a commanding position is available in rear of the gun which allows of both gun and target being seen at the same time, an aiming post can be quickly planted in exact alignment between gun and target by an assistant aligning it from that position.

2. Indirect Fire with the Map.

The map must be at least 1-20,000 and contoured.

A. To obtain direction:

Method I.—**By map and compass.**

(1) The position of the gun on the ground must be accurately fixed on the map.

This is done:

(a) From details on the ground and map.
(b) If (a) is not possible, by resection.

Any of the methods previously described may be used.

Where time permits, greater accuracy is insured by employing one method and checking with another.

(2) The magnetic bearing from the gun to the target must be found.

To do this:

(a) Draw a line on the map from the gun position to the target.
(b) Using the protractor, measure the bearing this line makes with any North and South grid line. This is the grid bearing from the gun to the target.
(c) Convert this bearing to magnetic.

The variation of the compass must be determined for each compass for the particular map in use, and should be constantly checked.

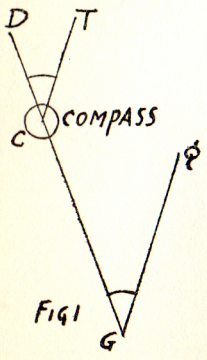
(3) To lay the gun on the magnetic bearing so obtained.

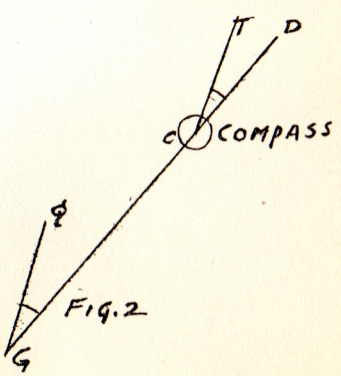
This can be done in the following ways:

(a) Place a post (not more than 6 inches high) on the gun position and place the compass on top of the post. Rotate the compass until it reads the required bearing.
Align two aiming posts on this bearing. Place the gun, with the center of the cross at the bottom of the socket, immediately over the post and lay on the aiming posts.
(b) The compass frequently, owing to the presence of iron, should not be used at the gun position. Take the compass away and more or less in the required line of fire, either in front of, or behind the gun.

Two cases now occur:

1. COMPASS IN FRONT OF GUN.





The figures show:

1. CG the bearing from compass to gun.
2. CD the back bearing.
3. CT the bearing on which the gun is required to fire.
4. Gg the line of fire obtained by laying off the angle gGC, which = the angle TCD.

Since the angle gGC = the angle TCD, gG is parallel to CT, and the gun is laid on the bearing required.

Rule:

1. Take the compass 30 to 50 yards in front of the gun more or less in the direction of fire. Lay the gun on the compass. Take the bearing CG of the gun.
2. Obtain the back bearing CD.
3. Obtain the angle between this bearing and the one on which it is required to lay the gun (i. e., CT). This is the angle TCD.
4. The observer at C now turns his back on the gun, and faces the direction CD; if the bearing on which it is required to fire the gun (i. e., CT) lies to his right, the gun lays off the angle TCD to the right; and if to his left the angle TCD is laid off to the left.

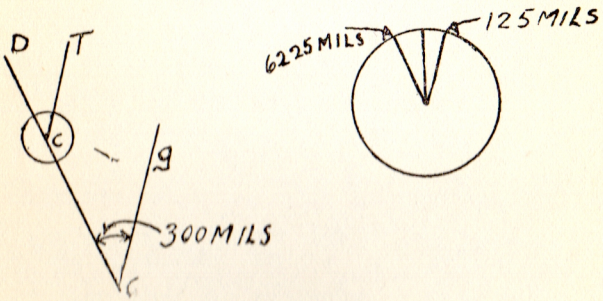
The gun is now laid on the required bearing in the direction Gg, which is parallel to CT; and an aiming post is put out.

Example: To lay on a gun on a magnetic bearing of 125 mils.

Supposing—

(I) It is found that bearing CG = 3025 mils.
(II) Adding 3200 mils, the back bearing CD = 6225 mils.
(III) The difference between a bearing of 6225 mils and the bearing required = 6400 — 6225 +125 = 300 mils.
(IV) Facing CD the bearing CT lies to the right.

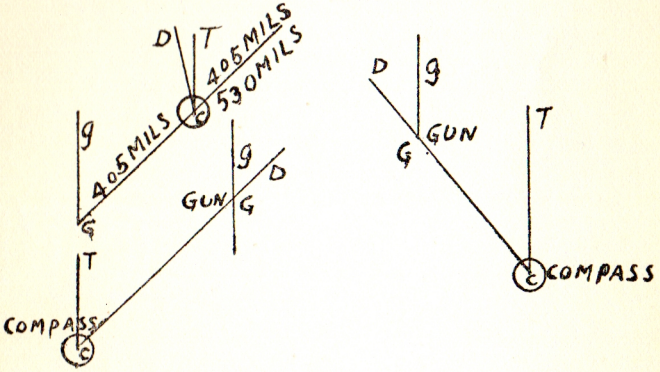
Therefore the gun lays off 300 mils to the right.



Or again it may be found that:

(I) Bearing CG = 3730 mils.
(II) Subtracting 3200 mils the back bearing, CD = 530 mils.
(III) The angle TCD = 530 — 125 = 405 mils.
(IV) Facing CD the bearing CT lies to the left; therefore, the gun lays off 405 mils to the left.

COMPASS BEHIND GUN.

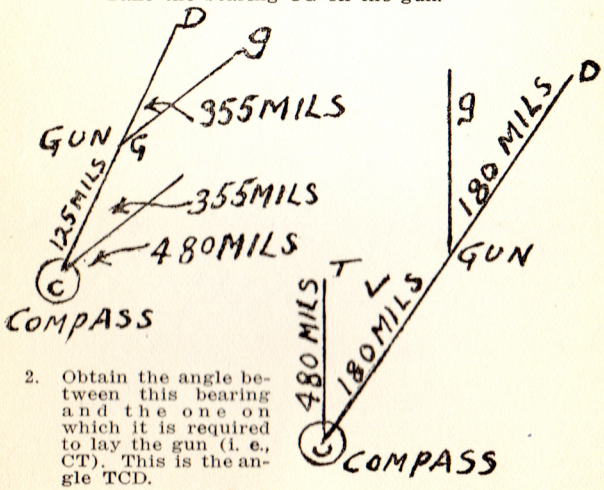


(I) CG the bearing from compass to gun.
(II) CT the bearing on which the gun is required to fire.
(III) Gg the line of fire obtained by laying off the angle gGD = angle TCD.

Since the angle gGD = angle TCD, gG is parallel to CT, and the gun is laid on the bearing required.

Rule:

1. Take the compass 30 to 50 yards behind the gun more or less in the prolongation of the line of fire, lay the gun on the compass. (After laying on the compass the gun must swing through 3200 mils before the final operation of laying on the target.)
   Take the bearing CG on the gun.



2. Obtain the angle between this bearing and the one on which it is required to lay the gun (i. e., CT). This is the angle TCD.

The observer at C now faces the gun if the bearing on which it is required to fire the gun lies at his right the gun lays off the angle TCD to the right; and if to his left, the angle TCD is laid off to the left.

The gun is now laid on the required bearing in the direction Gg, which is parallel to CT; and an aiming post is put out.

Example: To lay a gun on a magnetic bearing of 480 mils.

Supposing—

(I) It is found that bearing CG = 125 mils.

(II) Difference between a bearing of 480 mils (i. e., CT) and 125 mils = 355 mils.

(III) Facing CD the bearing CT lies to the right, therefore the gun lays off 355 mils to the right. Or, again, it may be found that:

1. Bearing CG = 660 mils.
2. Difference between a bearing of 480 mils (i, e., CT) and 660 mils = 180 mils.
3. Facing CD the bearing CT lays to the left, therefore the gun lays off 180 mils to the left.

METHOD 2. BY MAP AND REFERENCE OBJECT.

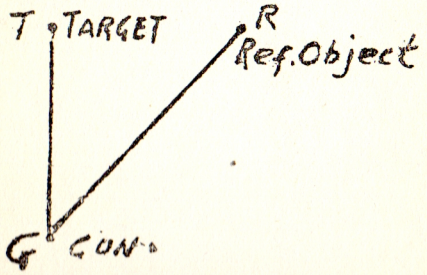
(1) The position of the gun on the ground must be first accurately fixed on the map.

(2) A reference object, which is both marked on the map and visible from the gun, is next selected.

A line is drawn on the map:

(a) From the gun position to the target—G.T.; and

(b) From the gun position to the R.O.—G.R.



The angle TGR is now measured with a protractor. The gun lays on the R. O. and taps off the angle TGR, and an aiming post is put in the direction obtained. The gun is now aligned on the target.

The angle TGR may be measured with a protractor without drawing any lines—but these are an aid to accuracy.

Where the position of the gun can be found from the detail on the ground, all errors arising from the use of the compass are avoided.

METHOD 3. BY MAP, REFERENCE OBJECT AND COMPASS.

A modification of Method 2 is necessary where no suitable reference exists which is marked on the map and is visible from the gun.

Select a reference object on the ground, or if necessary place one out. Take the compass bearing from the gun position to the reference object.

Find from the map the bearing on which it is required to fire the gun. Find the difference between these bearings and lay off the angle obtained from the reference object.

After the gun has been laid for direction by any of the methods given above, it is necessary at **the time of firing,** to make correction for wind.

B. **To Obtain Elevation.**

(1) On the map, measure the range from the gun to the target and note:

(a) The gun contour.
(b) The target contour.

The difference between the gun contour and the target contour is the vertical interval (V.I.).

(II) The quadrant elevation is now found:

Q. E. = Angle of departure + or — Angle of Site.

To obtain the angle of site use the formula:

$$\text{Angle of site in mils} = \frac{\text{V.I.} \times 1000}{\text{H.E}}$$

where V.I. = Vertical Interval
H.E. = Range,
and both are measured in the same unit.

(III) At the time of firing the gun, correction for atmospheric influences must be made, by adding to or subtracting the necessary correction from the Q. E.

(IV) To put the elevation on the gun.

Elevation is put on the gun with the clinometer.

1. Set the clinometer at the required reading.
2. Without holding, place the clinometer on the gun and elevate or depress the gun until the bubble is centered. Move up the rear sight slide until the point of aim is on the auxiliary aiming mark.
3. Take the holding and relay on the auxiliary aiming mark, using the elevating wheel, and not moving the rear sight slide.

This method obviates the error arising from a difference in holding when putting on elevation and when firing.

IN CASE OF LOSS OR DAMAGE TO CLINOMETERS ALL MACHINE GUN OFFICERS MUST KNOW HOW TO PUT ON ELEVATION BY MEANS OF AN ORDINARY SPIRIT LEVEL.

How to Put On Elevation By Spirit Level.

Four cases may occur, as follows:

1. The quadrant elevation is positive, and auxiliary aiming mark can be seen or put out.
2. The quadrant elevation is negative, and auxiliary aiming mark can be seen or put out.
3. The quadrant elevation is positive and auxiliary aiming mark cannot be seen or put out when gun is level and the sights are at zero.
4. The quadrant elevation is negative and auxiliary aiming mark cannot be seen or put out when gun is level and sights are at zero.

Proceed in all cases as follows:

Level gun by spirit level. Then:

Case 1.—Set rear sight at zero and select a natural aiming mark (or place out an artificial one) at least 100 meters away from the gun. Set rear sight at range corresponding to quadrant elevation, and relay on the auxiliary aiming mark.

Case 2.—Set rear sight at range corresponding to angle or quadrant elevation, disregarding sign. Select a natural aiming mark (or place out an artificial one) at least 100 meters away from the gun. Set sight at zero, and relay on the auxiliary aiming mark.

Cases 3 and 4.—Run up rear sight until a natural (or artificial) aiming mark is visible at least 100 meters away from the gun. Note range on tangent sight, and convert it to an angle. In case 3, add to, and in case 4, subtract from, this angle, the angle of quadrant elevation it is desired to put on the gun. and convert the answer to a range. Set rear sight at this new range, and relay on auxiliary aiming mark.

MAINTAINING LAYING.

After a gun has been laid for direction and elevation by any of the means described, an aiming post is put out in order to maintain direction and elevation. The rear sight slide is set so the sights are aligned on the mark and the laying is maintained by relaying on the aiming mark between bursts. In addition, the elevation should be frequently checked by the clinometer.

Inaccurate laying on the auxiliary aiming mark can be avoided only by thorough training. Too much stress cannot be laid on this part of the machine gunner's training, as failure in accurate laying may lead to fire which is dangerous or demoralizing to our own troops.

Machine gunners should be tested in aiming from time to time by the "triangle of error" method.

Where no form of artificial aiming mark is available, some natural object on the ground may be selected. This should be regarded only as a makeshift and not taught as a general practice.

CLEARING THE OBSTRUCTION.

In all cases where an obstruction exists between the gun and the target, it is necessary to insure that the shots will clear the obstruction before opening fire.

To do this:

1. After the gun has been laid for direction and elevation, adjust the rear sight to read the range from the gun to the top of the obstruction. If on looking along the sights the obstruction is not visible, the shots will clear.

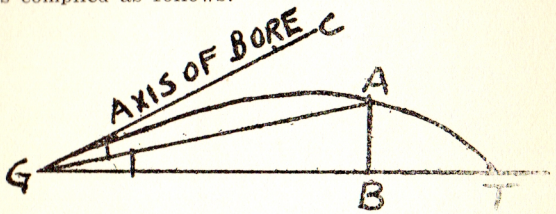
If the line of aim barely clears the obstruction, the lower half of the cone will strike the obstruction.

2. If the distance to the obstruction is under 50 meters, set the sights at 500 meters (the gun being already laid for direction and elevation); if, on looking along the sights the obstruction is not visible, the shots will clear.

3. If the obstruction is invisible (such as the summit of a hill hidden by a false crest) neither of the methods given above will apply, and the clearance may be determined by obtaining the Q. E. to the obstruction and the Q. E. to the target. In order to clear, the latter must exceed the former by at least half the depth of the cone.

TRAJECTORY TABLES.

The trajectory table for positive quadrant elevation is compiled as follows:



To find the height of the trajectory at a distance GB when firing at a range GT.

By definition angle TGC = Angle of departure for range GT, and assuming the rigidity of the trajectory.

By definition angle AGC = Angle of departure for range GA.
= Angle of departure for range GB.

(GA = GB approximately, the angle AGB being small.)

But angle BGA = angle TGC — angle AGC.
= angle of departure for range GT— angle of departure for range GB.

Now applying the V. I. formula:

$$\text{V. I.} = \frac{\text{S} \times \text{H. E.}}{1000}$$

and remembering S = angle BGA = angle of site
V. I. = AB
H. E. = GB

the clearance AB = (Angle of departure for range GT — angle of departure for range GB) × GB / 1000

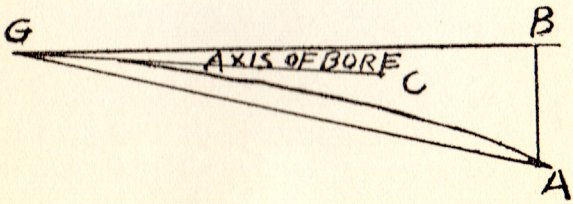
Example: To find height of 1,700 meters trajectory at 1000 meters.

Angle of departure for 1700 = 48.4 mils.
Angle of departure for 1000 = 16.6 mils.

$$\text{AB} = \frac{(48.4 - 16.6) \times 1000}{1000} = \frac{31.8 \times 1000}{1000} = 31.8 \text{ meters.}$$

The trajectory table for negative quadrant elevations is compiled as follows:

HORIZONTAL PLANE.



To find the depth of the trajectory below the horizontal plane through the gun position at a distance GB when firing with a quadrant elevation = angle BGC.

By definition angle BGC = QE

By definition angle AGC = Angle of departure for range GA

= Angle of departure for range GB

GA = GB (approximately)

But angle BGA = Angle BGC − angle AGC.

Now applying the V. I. Formula, and remembering

S = Angle BGA = Angle of site.

V. I. = AB

H. E. = GB

$$\text{Then AB} = \frac{(\text{QE} + \text{angle of departure for range GB}) \times \text{GB}}{1000}$$

Example: Supposing a negative angle of Q. E. of 35 mils.

To find depth of the trajectory below horizontal plane at a distance of 1000 meters.

Then angle of departure for 1000 meters = 16.6 mils.

$$\text{AB} = \frac{(35 \text{ mils} + 16.6 \text{ mils}) \times 1000}{1000} = 51.6 \text{ meters.}$$

In addition, all graphs and other aids to determine clearances without calculation are based on these Trajectory Tables.

NIGHT FIRING.

The tactical use of machine guns demands that fire should be effectively applied at night as well as by day. The means employed will vary according to circumstances.

Four cases can usually occur:

1. The gun is brought up, laid by day, and left in position ready for firing at night.

2. The gun is brought up, laid by day, removed for other work, and brought back again after dark.

3. The gun is brought up into position for the first time by night, but arrangements have been made during daylight.

4. Arrive by night for the first time, and all arrangements to be lone during the hours of darkness. (The following abbreviation is employed: "A.A.M." for "Auxiliary Aiming Mark.")

Case 1. Procedure by Day.

a. Obtain the range to the target and lay the gun on it.

b. Record the required direction and Q. E. by checking the direction dial and the elevation with the clinometer.

c. Put a sentry over the gun to insure that it is not touched.

Procedure by Night.

a. Put out a luminous A.A.M.; adjust the rear sight and the position of the A.A.M. until the sights are aligned on it (taking care that the direction and elevation of the gun are not altered).

b. Direction and elevation can not be maintained by relaying on the A.A.M.

Notes:

1. If the target is not visible, indirect means must be employed to lay the gun.

2. It may be possible to put out an A.A.M. by day unseen by the enemy.

If several targets are to be engaged, a separate A.A.M. must be used for each, and the respective readings of direction dial and clinometer noted. At night the gun can be laid on any desired target by means of the dials; direction and elevation can be maintained as in ordinary indirect fire.

Case 2. Procedure by Day.

a. Obtain the range to the target and lay the gun on it.

b. Put out an auxiliary aiming mark which can be replaced at night by a luminous mark.

c. Place a peg under center of tripod head to mark the correct position and note the position of the legs and trail.

d. Note the Q. E. by checking the elevation on the gun with the clinometer.

When replacing at night:

A. Mount the tripod in exactly the same position over the peg, and replace the gun.

B. Lay the gun with the clinometer.

C. Adjust the rear sight on the A. A. M. (which must be illuminated).

D. Gun is now laid on target; direction and elevation can be maintained by relaying on A. A. M.

Notes:

1. In soft ground it is advisable to place the A.A.M. some distance from the gun (say 25 meters) so that errors in elevation due to possible sinking may be minimized.

Case 3. Procedure by Day.

a. Drive in a peg about six inches high, to mark position over which tripod will be mounted at night.

b. Put in a second peg to give direction. This can be done by direct alignment if target is visible, or by compass bearing.

c. Obtain Quadrant Elevation.

Procedure by Night.

A. Mount tripod over peg (a); center of socket must be exactly over peg.

B. Place a luminous A.A.M. on peg (b); this will give direction.

C. Put on quadrant elevation by most convenient method.

D. Maintain direction and elevation by the A.A.M.

Case 4. Procedure.

Ordinary indirect fire using luminous compass for placing out A.A.M.

The compass bearing is the most suitable means of putting on direction. The clinometer is the most suitable means of putting on elevation. Maintain direction and elevation by the A.A.M.

Notes:

1. Night Aiming Mark:

   a. Experiments with aiming marks covered with luminous paint have not proved successful. Even on a dark night such aiming marks require very frequent exposure to artificial light in order to retain the necessary luminosity, and even then afford no definite point of aim. Another objection is that such aiming marks cannot be seen at all in the "half-light" of dawn or dusk, or on a moonlight night.

   b. Lamps containing oil burners or candles are a constant source of trouble because the lamp must be lighted before and extinguished after each target is engaged. If this is not done the mark becomes obscured by the smoke of combustion, and in the case of a candle the lamp becomes hot and the candle melts.

   c. The most satisfactory aiming mark is a suitable box fitted with an electric light.
   The light can be switched on from the gun position and can be put out as soon as the firing is completed. The box is easily carried and is not likely to break during transport.
   The aiming mark is 12 inches wide, and therefore, when placed 12.8 meters, or 14 yards, from the gun, gives a traverse of 24 mils. This is a great advantage over "point" aiming marks, where the limit of traverse has to be calculated.

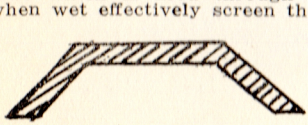
   With this aiming box, used in conjunction with the luminous sights, any type of indirect fire, including barrage fire, can be performed by night with accuracy.

2. An Electric Torch is essential at the gun for reading graduations on the direction dial and tangent sight, and for setting the clinometer. Care must be taken to cover the light as much as possible and prevent its being seen from the front.

3. Depression Stops and Traversing Stops, when set correctly, automatically insure the safety of our own infantry, and thus diminish the strain on the firer. They must be carefully set and checked and their use does not excuse the firer from the usual precautions.

4. Flash Obscurers have been produced which effectively conceal the flash from view, but they invariably disperse the cone to such an extent that they make overhead fire impossible. Consequently there is no pattern which can be recommended.

On the other hand, it has been proved experimentally that screens of canvas or sandbags have no effect on a cone which is fired through them, and such screens when wet effectively screen the flash.



Care should be taken to screen the flash at the sides as well as at the front. (See Diagram.)

5. When the firing is done from positions some distance behind our front line, and especially when this is reached by overland routes, special precautions must be

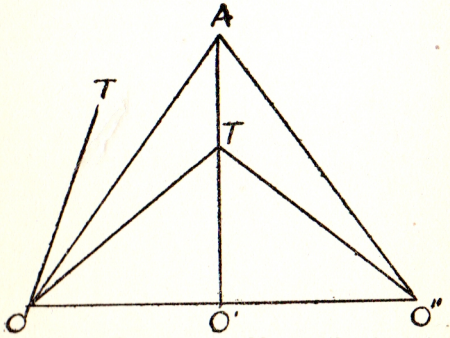
taken against endangering friendly troops who are passing near the gun position.

This is done by posting sentries or by wiring in the danger area. The safety of working parties and patrols in No Man's Land must be secured by liaison with battalions.

PARALLAX

Parallax is meant the apparent change in the relative positions of two objects because of a change in the position of the observer. Specifically, the term parallax is used in the discussion of problems in fire direction to denote the change that occurs in the horizontal angle subtended by target and reference point, or by the target and aiming point, because of a movement of the post of the observer to the right or left.

For example, referring to the diagram let O, O′ and O″ be three successive positions of an observer. Let T be the target and A the aiming point.



From O, the observer would see the target to his right of the aiming point, at O′ target and aiming point would lie in the same line, while at O″ the target is seen to the observer's left of the aiming point.

In its practical application to the direction of machine gun fire, cognizance must be taken of this fact in the designation of targets and in the computation of firing data when the gunner uses an aiming point instead of the target for the purpose of giving the proper direction to his piece.

Referring again to the diagram, assume the gun to be at O and the observer at O″. The observer finds the angle TO″A to be 14 mils, and, without considering the parallax, he tells the gunner at O to use A as an aiming point and set his sight with 14 mils left windage. Obviously, the gunner's fire would be directed along the line OT′ instead of the line OT as it should be.

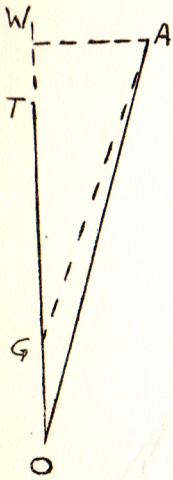
There are, in general, three cases in which correction for parallax must be made.

1. When the observer is in front or in rear of the gun in the plane of fire.

2. When the observer is on a line thru the gun approximately normal to the plane of fire and

3. When the observer is neither in the plane or fire nor on a line thru the gun approximately normal to it.

These three cases will be discussed in turn.



When the observer is in rear of the gun in plane of fire.

Given OG, OA, TOA.
To find TGA.

Knowing the distance OA and the angle TOA (in mils), the width WA (in meters) is found.

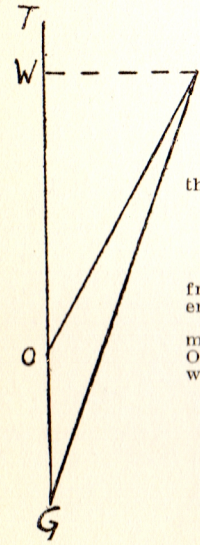
For small angles, such as that at O, it may be assumed for all practical purposes that GA = OA — OG.

With this value of GA and the width in meters of WA known, then the angle TGA (in mils) is readily computed.

OA = 1800 meters
OG = 300 meters
TOA = 20 mils

$$WA = \frac{1800 \times 20}{1000} = 36 \text{ meters}$$

$$TGA = \frac{36 \times 1000}{1500} = 24 \text{ mils}$$



When the Observer is in Front of the Gun in the Pane of Fire.

Given OG, OA, TOA.
To find TGA.

Knowing the width WA in mils from O and the distance OA in meters, find the width WA in meters.

Then knowing the width WA in meters, and the distance GA (GA = OA plus OG) in meters, find the width WA in mils from G.

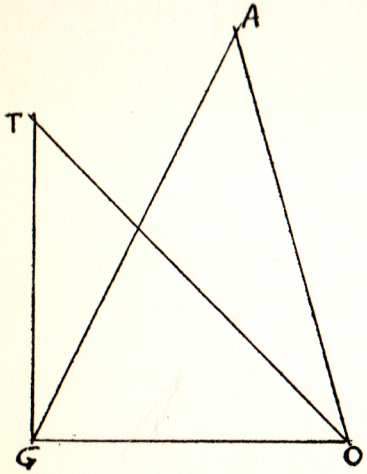
Example:

OA = 1500 meters
OG = 500 meters
TOA = 10 mils

$$WA = \frac{1500 \times 10}{1000} = 15 \text{ meters}$$

$$TGA = \frac{15 \times 1000}{2000} = 7\tfrac{1}{2} \text{ mils.}$$

When the Observer is on a line thru the gun approximately Normal to the Plane of Fire.



Given

OA, OT,

OG, TOA.

To Find

TGA.

In this case it can be assumed, for all practical purposes, that TG = TO and that AG = AO.

Then, knowing AO and OG, the angle GAO, in mils, can be found; and knowing TO and OG, the angle GTO, in mils, can be found.

Now from an elementary geometrical principle, it is known that the sum of the angles GTO and TGA is equal to the sum of the angles GAO and TOA.

Hence TGA = GAO plus TOA — GTO.

Example:

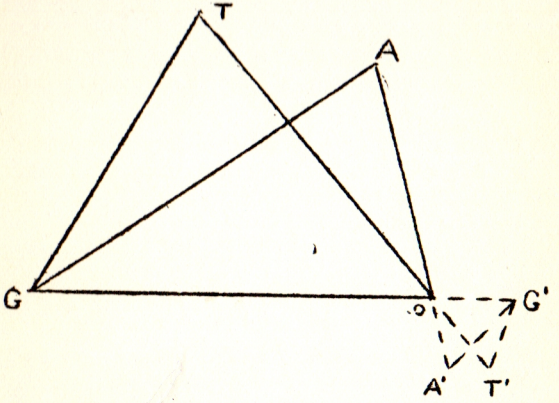
Let OA be 3000 meters.
OT be 2100 meters.
OG be 75 meters.
TOA be 17 mils.

hen $GAO = \frac{75 \times 1000}{3000} = 25$ mils.

$GTO = \frac{75 \times 1000}{2100} = 36$ mils.

Hence TGA = 17 + 25 — = mils.

When the observer is neither in the Plane or Fire **nor** on a line thru the Gun approximately Normal to the Plane of Fire.



To find Angle TGA.
Given OA, OT, OG, Angle TOA.

Without going into involved trigonometric computations, a simple method of solving this problem is to do it graphically on the ground.

Selecting some convenient reduced scale, say 1 foot to 100 meters, the observer measures off with this scale a distance OA′ to represent the distance OA and places a mark at A′ in line with O and A. Similarly, on the same reduced scale, he places marks at G′ and T′; OG′ being the representation of OG and in prolongation of GO; and OT′ being the representation of OT and in prolongation of TO.

The observer now may go to G′ and actually measure the angle T′G′A which is equal to the angle TGA, the result he is seeking.

If moving to G′ would be likely to result in betraying his position, or if for any other reason it be inexpedient actually to measure the angle T′G′A′ from G′, then it may be found thus:

The observer measures the angles OA′G′ and OT′G′. He already knows the value of the angle TOA which is equal to the angle T′OA′.

Then

TGA = TOA plus OA′G′ — OT′G′.

This method can be used in any case.

This method of determining the correction for parallax also is applicable in the other two cases, i. e., when the observer is in the plane of fire and when he is on a line thru the gun normal to the plane of fire.

It is simpler, and may be more convenient to solve the problem by constructing the ground map along the lines OG, OT and OA, rather than in prolongation of them.

POSSIBLE ERRORS IN INDIRECT FIRE.

Erors at the target may be divided into two kinds:

1. Lateral errors.
2. Errors in range.

Lateral errors occur in obtaining and putting on direction. Consider the different methods in use:

(a) Posts alone:
The only lateral error possible is caused by inaccurate alignment of the gun or posts. The remedy for this is careful alignment. Error in determining the gun position will not matter.

(b) Map and protractor, compass and post:
There are two possibilities of lateral error in this—Compass errors: There will be considerable unless what we may call the "characteristics" of a compass are studied and allowed for. In the first place the officer must know the error of his compass.
Secondly, he must realize that the presence of iron in the neighborhood will affect its accuracy. It may prove positively dangerous to our own troops to rely on a compass in an emplacement with a large amount of iron in it, or resting on an iron gate, or within a yard or two of a gun. A revolver or steel helmet may also have a large effect. However, if carefully used, with due regard to this characteristic, a good compass will give very accurate results.

(c) Map, protractor, compass and R. O. (R. O. not marked on map):
The possibilities of error, using this method, are exactly the same as in (b). The diagram shows that, with an accurate compass, the lateral error at target is exactly the same as at the gun position.

(d) Map, protractor, and R. O. (R. O. marked on map):
Possibilities of error in this method are GREAT unless certain precautions are observed. For instance, the diagram shows that under certain circumstances moderate errors (i. e., range or lateral) made in locating the gun position may lead to serious lateral errors at the target. If properly used, however, this method will be the most accurate of all (except (a)).

Precautions to be observed are as follows:

1. Use a R. O. near the target and subtending a small angle at the gun. A moment's thought about positions usually chosen for indirect fire will show that very often this will not be possible.
2. If the above is unattainable, choose a R. O. at as long a range from the gun as possible (even several miles away if there is one, provided it is marked on the same map sheet as gun and target) and do not have the angle subtended by R. O., gun and target any larger than can be helped.
If these precautions cannot be observed, it will be best either to use one of the other methods, or else to check the gun position as closely as possible by resection (using near objects for the

purpose) so that the error in locating it may be reduced to a minimum.
FINALLY—insist on the necessity for a fair amount of traversing and a slight amount of searching for all indirect fire at a point target.

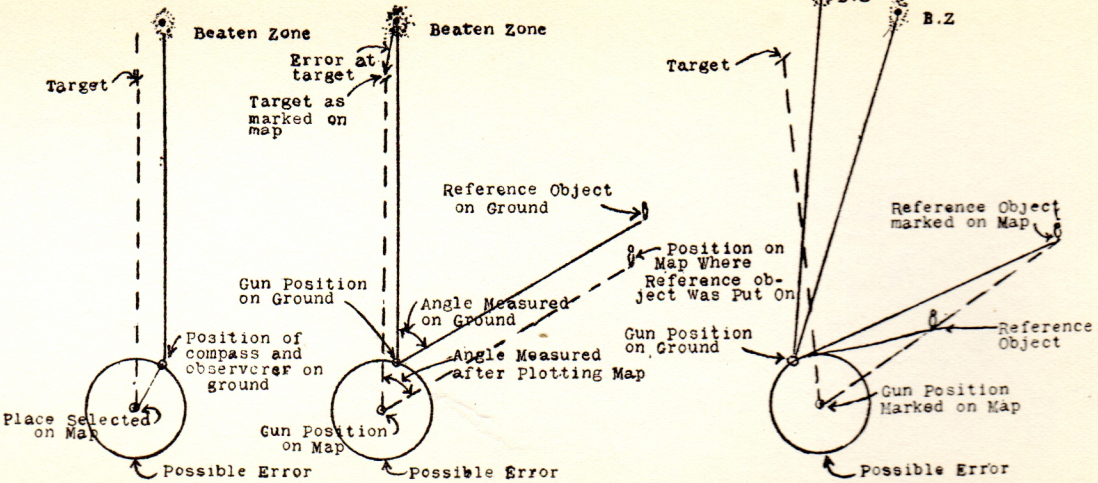
The most probable errors which affect indirect laying have been described in the preceding analysis. These errors are now summarized in order to assist the machine gun company commander to draw up his training program.

Errors on the part of officers:

(I) Inaccurate map work.
(II) Inaccurate compass work, which may affect both the fixing of the gun position and the laying out of the line of fire.
(III) Choice of reference object.
(IV) Inaccurate calculations and failure to allow for atmospheric conditions and changes.
(V) Use of instruments such as clinometers, angle of site instruments, when not in accurate adjustment, and of worn-out material such as barrels, etc.

Errors on the part of personnel:

(I) Inaccurate aiming.
(II) Inaccurate placing of elevation on the gun.
(III) Inaccurate use of traversing dials, T-aiming marks, and other devices.
(IV) Failure to attend to care and cleaning P. B. D. & A., etc.
(V) Failure to comprehend or carry out instructions.



Error in Locating the Gun Position on the Ground, and the Relative Error in Applying Fire.

Reference Object Selected on Ground and Plotted on Map.

Gun Position Selected on Map and Found on Ground.

Magnetic Bearing of Target Accurately Determined from Map.

Using a Reference Object Marked on the Map, and Showing Subsequent Error on Ground When Position is not Accurately Located.

Showing also that the Error is Greater When the Reference Object is Selected Near the Gun Position.

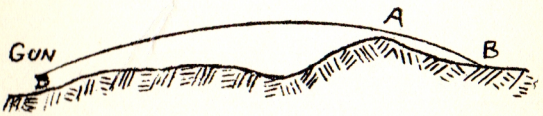
SEARCHING REVERSE SLOPES.

It may sometimes be desired to search the reverse slopes of a hill occupied by the enemy, where he is under shelter from short range fire.

Reverse slopes are often chosen by the enemy as suitable areas where troops may be disposed preparatory to attack, or may maneuver free from observation. It is, therefore, necessary to know how much ground may be brought most effectively under machine gun fire. A suitable table enables the machine gun officer to search the reverse slope of a hill, and is constructed on the following basis:

If a gun is placed at such a distance from the crest that the cone, just passing over it, will fall at a steeper angle than the slope of the ground on the other side of the hill, then fire effect will be brought to bear on the reverse slope. No endeavor has been made to fit the trajectory exactly to the reverse slope, as the difficulties and variables in the problem are so many that small errors would upset the results. Traversing and searching would be employed for the same reasons as govern all forms of indirect fire.

In order to search a reverse slope effectively, the gun must be placed at such a distance from the crest that the fall of the bullet is steeper than the slope of the ground.



The table has been compiled to enable the machine gunner to do this without making elaborate calculations.

1. **Method of Using Table.**

(I) Find the fall in meters per 100 meters of the slope. To do this it is best to find the fall for several hundred meters of the slope, and then calculate the average fall per hundred meters. (Suppose the fall is 6 meters per 100 meters).

(II) Draw a line on the map representing the probable line of fire. This will be so as to engage the target in enfilade when possible.

(III) Observe from the map whether the gun is likely to be above or below the crest.

(IV) Suppose it is above. On the right half of the table (Gun above Crest) and in the top column, find the figure 6, and notice the range in the column beneath it (i. e., 1,500 meters).

(V) Measure back from the crest 1,500 meters along the line of fire.

(VI) Find the difference between the height of this point and the height of the crest (say 20 meters).

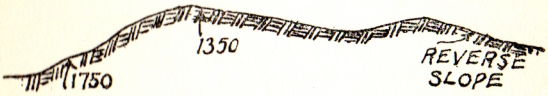
(VII) Find 20 in the center column, and reading along the column to the right, find the range below the 6 in the top column (i. e., 1,650 meters).

(VIII) Measure back 1,650 meters from the crest, along the line of fire. The point thus found is the point at which to place the gun.

(IX) Knowing the gun position, and the position and the height of the crest, find by ordinary methods of indirect fire the direction and elevation necessary to hit the crest.

2. **Special Points.**

(I) In center cases both sides of the table may be satisfied.



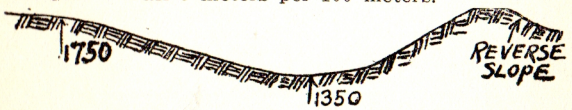
Example: Fall 5 meters per 100 meters.

Then, using the right side of the table (Gun Above Crest), the gun must be placed 1,350 meters from the crest. Or, using the left side (Gun Below Crest), the gun must be placed 1,750 meters from the crest.

In such a case, the controller can decide for himself which position is the best to occupy. In this example the question of clearance over the intervening crest must be considered.

(II) Neither side of the table may be satisfied.

Example: Fall 5 meters per 100 meters.



On measuring back 1,350 meters, the gun may be below the crest, and in measuring back 1,750 meters, the gun may be above the crest. In such a case, which will be extremely rare, choose a position between the two which is on the same level as the crest; generally the rverse slope can be engaged from this position.

(III) As the searching of reverse slopes is a special type of indirect fire, searching and traversing will be employed as usual, with the exception that searching will be limited on account of the sloping ground engaged and the consequent lengthening of the beaten zone.

If AB represents the length of the beaten zone on the horizontal plane, AC will represent the length of beaten

zone on the slope AC. In all cases AC will exceed AB.

(IV) The final position indicated by the table may be an impossible one, say, in a river or a marsh. In such a case a gun position should be selected further away from the slope rather than nearer to the slope.

By moving further back the range is increased, and consequently the angle of fall of the bullet, but by going nearer to the crest the angle of fall is decreased, and it may become impossible to search the reverse slope.

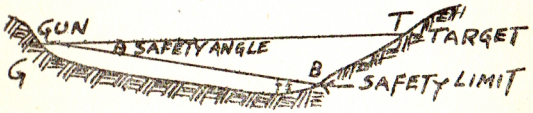
(V) Fire should be directed at the target, which may, or may not, be the crest of the hill. If the target is not the crest of the hill, calculations should be made to see the gun should be taken back to such a range that the obstruction will be cleared.

DIRECT OVERHEAD FIRE.

It has long been an accepted principle of Infantry tactics that, whenever the ground permits, an advance should be assisted by fire directed over the heads of the assaulting troops.

For this type of fire action, in which the safety of the troops whose advance is being covered is the primary consideration, the machine gun, by reason of its fixed mounting and the close grouping of its fire, is characteristically fitted.

The safety of the attacking troops is insured by the employment of a "Safety Angle," which is based upon the height of the mean trajectory above the position of our own troops.



The safety angle is measured vertically and is the angle between the line of site to target and the line from the gun to our own troops when they are at the safety limit.

Rules Governing the Use of Direct Overhead Fire.

1. The Clearance, as shown in the "Table of Clearances for Overhead Fire," will be used:
2. Direct overhead fire must not be employed if our own troops are more than 1800 meters from the gun.
3. The range to the target must be known to within 5%.
4. A worn barrel (one that has fired 15,000 rounds) or a worn tripod must not be used.
5. No. 1 must be an expert firer.
6. The tripod must be well dug in and firmly mounted.
7. The target and our town troops must be clearly visible.
8. Our own troops should be advised that overhead fire will be employed.

Notes on the Preceding Rules.

(1) In Rule 2, there is no limit to the range from the gun to the target. The erratic dispersion of the cone of fire necessitates the discontinuance of firing if our own troops advance beyond 1800 meters.

(2) Rules 3 and 4 are practical precautions for minimizing the errors allowed for in Rule 1, thus making the safety of our own troops absolute.

(3) In addition, the controller will allow for climatic conditions, especially for head winds.

(4) The calculation of the safety angles shown in the "Table of Clearances for Overhead Fire," is based on the following allowances:

(a) That a maximum error of 5% may have been made in the range, and 10% for bad holding, aiming, etc.

(b) That the lowest shot of the cone will pass 5 mils, or 10 feet (whichever be the greater), above the heads of our own troops, when the range to the target has been underestimated by 15% (5% and 10%) as noted under (a).

An example will best illustrate the method of computing the "Table of Clearances for Overhead Fire."

Assuming the troops are 1,000 meters distant, what safety angle is required in order that there shall be a clearance by the lowest shot of the cone of not less than 10 feet, or 5 mils, when the range is underestimated by 15%?

1. At 1,000 meters, 5 mils subtends 5 meters, which is greater than 10 feet.

2. Height of a man = 6 feet
= 1.83 meters
= 1.83 mils

3. The lowest shot at 1,000 meters is 2.8 meters below the mean trajectory.

2.8 meters subtends 2.8 mils at 1,000 meters. This makes a total of 9.63 mils (5 + 1.83 + 2.8) from the feet of our own troops to the mean trajectory of the cone, the lowest element of which just clears their heads by 5 mils. With the ordinate of 9.63 mils, that is, 9.63 meters, it is found that this mean trajectory corresponds to a range of 1,260 meters, which range is the least permissible with an underestimate of 15%.

To allow for this 15% error, there must be added $\frac{15}{85}$ of 1,260, which gives 1,482 meters (in even figures, 1,500) as the least range of the target when the troops are at a distance of 1,000 meters. The angle of departure for 1,482 meters is 36.5 mils. This includes the angle of departure for the range to our own troops, and in computing Column 2, which shows the "Clearance Required" in mils, the angle of departure to our own troops is deducted from the angle 36.5 mils; that is, 36.5 mils—16.6 mils (angle of departure for 1,000) = 19.9 mils (in even figures, -20 mils).

This is the safety angle required when our own troops are 1,000 meters from the gun.

Application of Safety Angles.

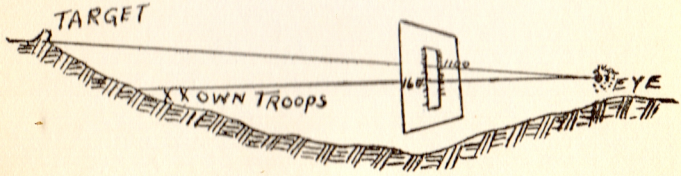
Method 1. By graticules:

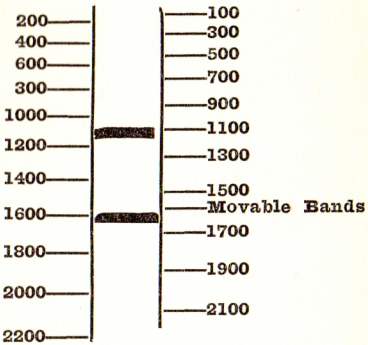
The officer in charge of the guns, during his preliminary reconnoissance, will ascertain if it be safe to fire, in the following way:

Ascertain the range to the target; align the graticule representing the range to the target, on the target.

(a) If the range to the target is 800 meters or less, see where the line on the graticule representing 1,350 meters cuts the landscape.

(b) If the range to the target is 900 or over, add 500 meters to the range to the target, and locate the point on the landscape cut by this line.
If this point located on the landscape is at or above the feet of our own troops, it will be safe to fire.





It will be more convenient to use the graticule card with two movable bands. Then, if the range to the target be 1,100 meters, one band is set at 1,100 meters, and the second at 1,600 meters. The angle subtended by the vertical distance between the bands will give the required safety angle.

Method 2. Rear Sight Method.

The gunner lays the gun on the target with the range required to hit it; without changing the elevation of the gun; he then runs up his sight an additional 500, but not less than than 1,350; that is:

(1) If the range to the target is 800 or under, adjust sight to 1,350.

(2) If the range to the target is 900 or over, add 500.

If the new line of aim is at or above the feet of our own troops, it is safe to fire, and fire can be maintained until our own troops advance beyond the point thus determined.

When the gunner raises his sight setting, he selects the point on the landscape up to which our own troops can advance with safety, and constantly checks his aim on this point. The fire up to the present will have been directed at the target, because initially the gun was laid on the target with the range to hit it.

Procedure When Our Own Troops Leave the Safety Limit.

(1) As the "Graticule Method" used by the officer, and the "Rear Sight Method" used by the gunner, will determine the same point on the landscape, when our own troops advance beyond this point, the gunner, unless otherwise ordered, will elevate the gun until his sights are aligned on the target. He will, therefore, be aiming at the target with the range to the target plus 500 meters on his sight, and the cone will fall approximately 500 meters beyond the target.

(2) Closer support will be rendered by keeping the line of aim on or slightly in advance of our own troops rather than by raising it on to the target as soon as the troops reach the line of aim. Instead of one big lift there will be several smaller ones with a consequent increase in the effectiveness of the support given the advancing troops.

In case the erratic movement of our own troops renders this difficult, a series of definite lifts may be prescribed.

In any event, the gunner must keep his line of aim on or beyond the friendly troops.

Whenever practicable, the controlling offiicer will order the gunner to follow the most suitable method described under (2), "Procedure When Our Own Troops Leave the Safety Limit."

Fire must cease when our own troops advance beyond the target.

Note:—If our own troops are less than 300 meters from the gun position, special precautions must be taken.

Note:—In the "application of safety angles" above, the safety angle has been based on the range to target, because that finally will be the range to our own troops.

INDIRECT OVERHEAD FIRE.

The clearance at any point over which fire is being directed is the vertical distance of the cone above that point.

When indirect fire is carried out over the heads of our own troops, the following rules must be adhered to in order to insure the safety of the troops.

1. The safety angle as shown in the table of "Clearances for Overhead Fire" will be used.

2. Our own troops must not be more than 1,800 meters from the guns.

3. Steps must be taken to prevent such extremes of traversing and searching as would violate (1). This is best done by using traversing and depression stops.

4. Calculations must be carefully checked and atmospheric conditions allowed for.

5. The rigidity of the firing platform is essential. This may be obtained by the use of a "T" base, or by any available method of insuring a firmly mounted tripod.

6. Elevation must be frequently checked by the clinometer.

7. The personnel must be highly trained in accurate aiming and relaying.

8. The maps used must be accurate and the scales not smaller than 1/20,000.

9. Worn barrels and tripods should not be used.

10. Our own troops should be warned when firing is going to take place.

11. Clinometers should be frequently tested.

The importance of the rigid platform may be better realized if it is remembered that a change of elevation of about 10 mils is caused if the front legs sink 1/3 inch while the rear legs remain fixed, and vise versa if the rear legs sink while the front legs remain fixed. As this error is neutralized by relaying on an auxiliary aiming mark, the necessity for constant and accurate relaying is again emphasized.

Methods of Finding the Clearance.

(a) Angular Method.

a. Determine the Q. E. to the target.
b. Determine the Q. E. to our own troops at the various distances they will be from the gun at any particular moment.
c. Deduct the Q. E. to our own troops from the Q. E. to the target.

d. If the difference so found is eqqual to or greater than the clearance in mils as shown in the "Table of Clearances for Overhead Fire", it will be safe to fire.

(b) **To Determine to What Point Our Own Troops Can Advance With Safety by Use of the "Table of Safety Clearance for Overhead Fire."**

As stated in the foregoing paragraph, determine the difference between the Q. E. to the target and the Q. E. to our own troops.

If our own troops are moving forward, a series of calculations can be made to determine the clearance at each position (and so long as this clearance is equal to or greater than the clearance in mils shown in the "Table of Clearances for Overhead Fire," it will be safe to fire).

Thus the farthest point from the gun at which there is the required clearances will be determined by reference to the "Table of Clearances for Overhead Fire."

(c) **To Ascertain From a Graph the Nearest Point to Which Our Own Troops Can Advance With Safety—Determine the Q. E. to the Target.**

1. Consider the contour of the gun position as Zero.

2. Draw in on the graph a cross section of the ground under the line of fire by plotting the relative heights of the gun position and ground at each 100 meters.

3. Plot the target.

4. This will give the mean trajectory used.

5. Find the point on the graph to which our own troops can advance and have the required safety clearance as shown in the "Table of Safety Clearances for Overhead Fire."

Example: See attached graph.

Assume Q. E. to target = 85 mils; target is 2,100 meters distant.

1. Can our own troops advance with safety to a point (A) 1,800 meters away from the gun?
Q. E. to our troops at this point = 67.5 mils.
Therefore clearance is 85 — 67.5 mils
= 17.5 mils
(A B on attached graph)

At 1,800 meters our own troops require a clearance of 40 mils.
Therefore they cannot advance with safety to this point.

2. Can our own troops advance with safety to a point (C) 1,400 meters from the gun position?
Q. E. to our troops = 42.5 mils.
Therefore, clearance is 85 — 42.5 mils
= 42.5 mils
(C. D on attached graph)

This clearance (42.5 mils) is greater than the required clearance (28 mils), therefore the troops can advance to a point nearer the target.

3. Up to what point can they advance?
At 1,550 meters (point E) the Q. E. to our own troops
= 52.5 mils
Clearance = 85 — 52.5 mils
= 32.5 mils (E F on attached graph)

The clearance required at 1,550 is 32.5 mils. Our own troops can advance with safety to a point (E) 1,550 meters from the gun position.

(a) **By Linear Clearances.**

The following is a method which may be used:

1. Determine the Q. E. to the target.
2. Transfer to equivalent range.
3. From "Tables of Ordinates" or from a Graph, determine the height of the mean trajectory at this equivalent range at the positions of our own troops.
4. Determine the Vertical Interval (difference in contour between the gun position and the position of our own troops.)
5. To determine the clearance—
   (a) If our own troops are on a higher contour than the gun position, deduct this vertical interval as found in (4 from the height of the ordinate as found in (3).
   (b) If our own troops are on a lower contour than the gun position, add this vertical interval as found in (4) to the height of the ordinate as found in (3).
6. If the clearance thus found is equal to or above the clearance in meters in the "Table of Safety Clearances for Overhead Fire," it will be safe to fire.

(b) To find the farthest point to which our own troops can advance with safety from the graph.

The principle is the same as that followed for angular clearances, but the linear clearances given in the table are used.

Section B

Barrage Firing

CONTENTS

Laying and Fire Control in Barrage Fire

General.

To enable the fire of the batteries to be controlled easily and fire applied to any target at will, it is necessary that all the guns of a battery should be laid initially on parallel lines of fire. These lines are called the "ZERO LINES OF FIRE" of the battery, and from these all changes in direction of fire are calculated. The guns of a battery are numbered from right to left.

In fixing the position of a battery on a map or to fire from calculations made from a map, the position of one gun is fixed as **accurately as possible** and this gun is used as the directing gun and from which all subsequent calculations for direction or alteration in direction are made. A flank gun is usually chosen as the directing gun.

Choice of Zero Line.

In selecting the zero line of a battery it is best to fix a line from which all targets likely to be engaged in the area alloted to the battery can be reached with a minimum change of direction. If required for a "barrage only," it will be found suitable to choose such a zero line that the directing gun (whether the left or right gun), will have its zero line on the corresponding limit on the flank of the line to be barraged.

To give quite accurate results, this method of parallel zero lines requires that the guns of the battery shall be at equal intervals from each other. If the guns are not at equal intervals, the error at the target for any gun is equal to the distance that particular gun is from the position it would occupy if the guns were at equal intervals. In the case of the two flank guns of the Battery, there will be no error due to unequal intervals between the guns.

When each gun is laid on a parallel line of fire, and aiming post is placed out in prolongation of the line of sight and each gun is then said to be laid on its ZERO LINE. The aiming post is called the "Zero Aiming Post." All calculations for change in direction are made from this line.

Method of Obtaining Parallel Zero Lines.

The method most suitable to the situation will naturally be used. The means usually available are as follows:

1. Using a reference object.
2. Using a compass.
3. Using a director.

Use of Reference Object.

When all the guns of a battery are laid off the same angle from the same reference object, the lines of fire will not be parallel unless:—

1. The reference object is at an indefinite distance, or
2. The reference object is in direct prolongation of the line of the guns of the battery.

Where a reference object cannot be obtained fulfilling the above conditions, proceed as follows:

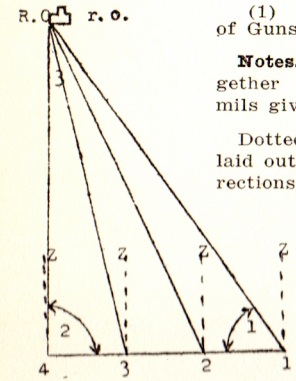
The flank guns will be mounted first and laid on each other, the aiming mark being the brass end of each steam tube. The reading on the direction dial of each gun will be noted. Each gun will then lay on the reference object and the reading on the dial again be noted. Each squad leader then calls out the angle through

which his gun has moved, e. g., No. 1 calls out—1040 mils, No. 4 (or whatever the number may be) calls out 2100 mils. The battery commander then adds the two angles together and deducts the sum of these two angles from 3200 mils, which gives a remainder of 60 mils, this being the angle at the reference object subtended by the front of the battery.

The 60 mils is then divided by the number of intervals between guns and the result is the number of mils of deflection that each gun should differ from its neighbor to produce parallel zero lines. In the case above quoted, assume the battery to be a 4 gun battery. The number of intervals between the guns would be three, therefore, 60 mils divided by 3 equals 20 mils. Suppose the reference object was straight in front of the left gun and on a line at right angles to the front of the battery; the order would be "No. 4 the directing gun," distribute 20 mils right. This order is treated in the same manner as an order to use combined sights, e. g., No. 4 repeats the order but does not lay off from the reference object. No. 3 calls out 20 mils right—distribute 20 mils; and lays off 20 mils to the right of the reference object; No. 2 calls out 40 mils right, distribute 20 mils and lays off 40 mils to the right of the reference object; No. 1 repeats, 60 mils right, distribute 20 mils.

Zero aiming posts are then put out in line with the new line of sight. This places all guns on parallel lines of fire.

SEE THE FOLLOWING EXAMPLES:

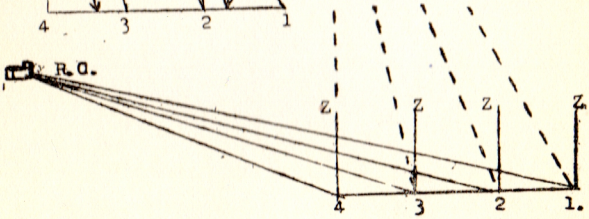


(1) Reference Object in Front of Guns.

Notes. Angles 1 and 2 added together and deducted from 3200 mils give angle marked (3).

Dotted lines show Zero lines laid out after calculation and corrections made.

Z is the position of the Zero Aiming Posts.

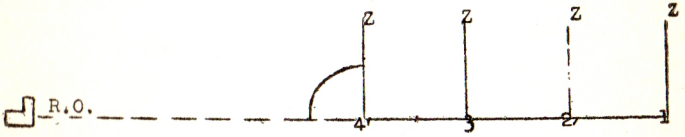


(2) Reference Object to Front of Guns.

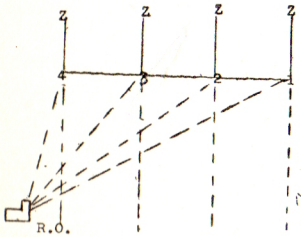
Note. In this case it is assumed that the Reference Object being too much to a flank for zero lines to be laid out as in Fig. 1, the battery commander wishing to have the lines at Right angles to the battery front, gives the order "all guns" "1000 mils. Right." The guns are then laid on the "dotted" lines as shown in the diagram. The order for "distribution" is afterwards given, and all guns are then laid on the short heavy lines as shown in the diagram.

(3) In this case all guns lay on Reference Object and turn through the same agle for Zero lines.

Reference Object on Flank of Gun.



(4) Reference Object behind guns.



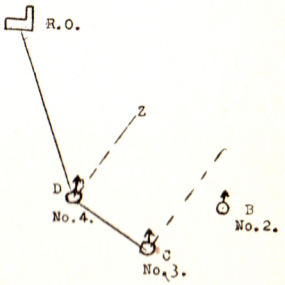
In this case all guns lines.
as in (1) above. The usual calculations and orders are given. When all guns are on the parallel dotted lines, the order "all guns" 3200 mils "Right" (or left) is given and all guns then as shown by heavy parallel lines.

(5) Reference Object not visible to all guns.

Two guns only are dealt with in the example.

The Reference Object is visible from D, so that No. 4 gun can be laid on its zero line.

No. 4 gun is visible from C.



To lay No. 3 gun on a line parallel to DZ:

The two guns will first lay on each other.

No. 4 gun will then be relaid on its zero aiming post, and the angle through which it has been switched read off from the Direction Dial.

This angle will be subtracted from 3200 mils, and No. 3 gun will switch through the angle thus found. No. 3 gun will then be laid on a line parallel to DZ.

Any gun can be laid on its zero line provided that its No. 1 can see either the reference object or a gun that has been laid on its zero line.

Using a Compass.

The compass is used in two ways.

(a) Laying out each line separately for each gun as in the ordinary indirect fire method, when the compass is used to give the direction; or can be used in conjunction with the compass tower.

(b) Using the compass as a form of director in the following manner:

(i) The compass bearing of the zero line from the Battery position having been determined, the battery commander will place himself at least a hundred yards in front of the guns, and on a line between the directing gun and the intended zero line, in order to save correction calculations. His procedure is as follows: Assume the zero line to be on a bearing of 3000 mils, the back bearing will therefore be 6200 mils. The battery commander facing the directing gun, moves to the right or left until the directing gun is on the bearing of 6200 mils.

(ii) All guns are then ordered to lay on the compass.

(iii) The battery commander will take a reading on the front of each gun in turn, squad leaders and No. 2 reading their direction dials when their gun is laid on the compass.

The battery commander then orders each gun in turn to move its line of sight through a horizontal angle equal to the number of mils that the bearing of each gun differs from the bearing of the directing gun, e. g., the reading of the compass on the directing gun (say No. 1 gun) on the Zero line is 6200 mils, the reading to No. 2 gun is 6250 mils; the Battery Commander orders "No. 2 50 mils left," the reading to No. 3 is, say, 6300 mils. The order would be "No. 3 100 mils left." Each gun is dealt with in turn.

Zero posts are then put out on the new line of site.

If the battery commander cannot go out in front of the battery he can do the same thing from behind, proceeding in a similar manner, but with the following modifications.

(i) The bearing will naturally be a forward bearing, so he moves to a flank until the directing gun is on the magnetic bearing of the zero line.

(ii) After the corrections described in the paragraph (iii) above have been applied, the order would ge given "All guns 3200 mils, Right (or left).

Notes. If desired, the battery commander can of course give the order direct, as follows: Assume the directing gun (say No. 1) to be on a bearing of 3000 mils. The compass reading on No. 2 is 2950 mils. The battery commander deducts 50 mils. from 3200 mils, then gives the following order: No. 2 gun, 3150 mils LEFT.

The first method is the more simple and less likely to allow errors to creep in, but the second method is slightly quicker.

Using the Director.

The principles in the use of the director are similar to those described above for the use of the compass. The detailed instruction for its use will vary according to the type of director employed. When a target is invisible to the guns, but can be seen from some point by the director, it is an easy matter for the guns to be put on to the target or put on zero lines by their laying on the director then giving the angles through which each gun must be traversed to put it on the zero line or on a target.

The director should, if possible, be put on the line joining the target and the directing gun, or the zero line of the directing gun, as described above when using the compass.

There may sometimes be occasions when the compass or director cannot be placed on the line joining target and the directing gun. Under these circumstances a correction will have to be applied before giving the angle for each gun to lay its zero line on.

This is the correction for parallax as given in indirect fire.

Angle for Zero Correction.

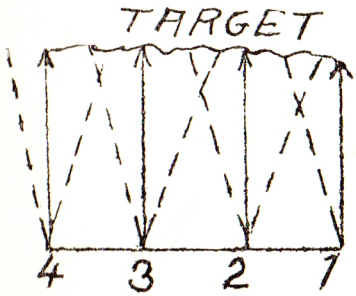
When guns are laid on a reference object, compass, or director for the purpose of eventually obtaining parallel zero lines, the angle through which they move from any of the above to their zero lines is called the "angle for zero correction."

Angle of Switch.

When a battery laid on parallel zero lines is required to change to direction of its fire, the lines of site of all guns are turned through a certain angle. This angle is called the "angle of switch" and is calculated from the zero lines. If therefore, the whole of the guns are originally laid on parallel zero lines it will be seen that if the same angle of switch is given to all guns, the guns will always be on parallel lines of fire, irrespective of the direction of the target from the zero lines.

Distribution of Fire.

When the guns of a battery laid on parallel zero lines, open fire, each gun must traverse a certain amount to the right and left of its line of fire, otherwise there would be gaps in the target on which no fire would be put. The general rule is that each gun will traverse 15 mils right and 15 mils left of its line of fire. If the target is of such a width as will be described later, a "gun angle of distribution" (which is explained in subsequent paragraphs) is order, and under these circumstances each gun must traverse the amount of that angle of distribution to the right and left of its new line of fire.



Target on same frontage as battery. Heavy lines show center line of fire for each gun. Dotted lines show limit of traverse of each gun. The overlap of the flank guns insure the target area of adjoining batteries being covered.

When a target has to be engaged which is wider than the front of the battery, some method of distributing the fire equally along the whole target front is needed. A method of doing this is as follows:

(i) Deduct the frontage of the battery from the frontage of the target.

(ii) Determine either by graph or by the formula.

$$\text{Difference between Target frontage and Battery frontage} = \frac{\text{(Range) Battery to Target} \times 1000}{\text{mils.}}$$

(iii) Divide the answer obtained in paragraph (ii) above by the number of gun intervals, and the result is the amount of deflection to be given to each gun **above that given by the gun next to it** on the side of the directing gun.

Example: The frontage of an eight gun battery with 10 yards intervals between guns is seventy yards.

The target covers a frontage of 200 yards.
200 yards—70 yards=130 yards.
Range to target is 2000 yards.

Applying formula

$$\frac{130 \times 1000}{2000} = 65 \text{ mils.}$$

Number of gun intervals is seven.
Therefore, 65 divided by 7 equals 9 mils (putting at nearest whole number).

The order would be (assuming No. 8 as the directing gun), "No. 8 directs" distribute 9 mils right.

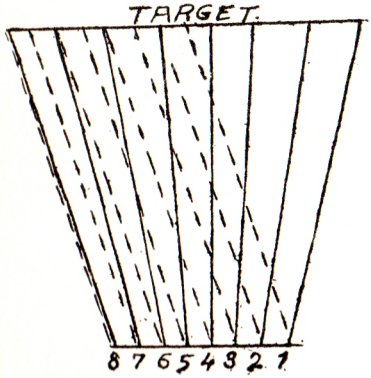
No. 8 calls out the order, but does **not** distribute.

No.	7	calls	out	"	9	mils	right —	distribute	9	mils."
"	6	"	"		18	"	"	"	9	"
"	5	"	"		27	"	"	"	9	"
"	4	"	"		36	"	"	"	9	"
"	3	"	"		45	"	"	"	9	"
"	2	"	"		54	"	"	"	9	"
"	1	"	"		63	"	"	"	9	"

The total angle obtained above, that is the 65 mils, is known as the "Battery angle of distribution"; the 9 mils given by each gun is called the "gun angle of distribution."

Each squad leader hearing the amount of deflection given by the **gunner next to him on the side of the directing gun,** merely adds the angle of distribution ordered, to the amount called out by his neighbor, and this is repeated in a similar way all down the line exactly on the same principle as a "Combined sight" order.

The result obtained is as shown in diagram.



Dotted lines show the original lines of fire on the angle of switch. Heavy lines show real lines of fire after the above method of distribution has been applied.

Note. It is assumed that the target line is continuous and the above portion is the area alloted to this battery so that the flank guns when traversing will overlap into the next sector.

Distribution on an Oblique Target.

It will sometimes occur in oblique barrages that a battery has to put its fire on a target oblique to the front of the battery. If the angle which the target would make with a line drawn at right angles to the battery front is not less than 1400 mils, or more than 2000 mils, this angle of obliquity can be disregarded.

If the angle is greater, calculations for the battery angle of distribution are made in one of the following ways:

(1) If working from a map, the target not being visible from the gun position, this information can be obtained as follows:

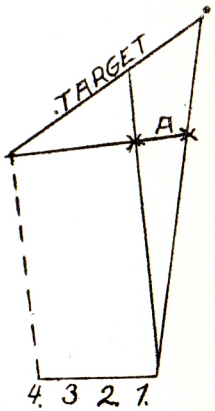
(i) Draw on the map a line joining the flank gun nearest the end of the target, and a similar line parallel to it from the gun on the opposite flank.

(ii) Now draw a third line from the farthest end of the target to the flank gun which is more nearly opposite to it. (See diagram.)

(iii) Now draw a line from the nearest end of the target and **at right angles** to the two parallel lines previously made; continue this line until it joins the third line joining the farther extremity of the target and the other flank gun.

(iv) Measure the length of this line from the point of intersection with the second parallel line where it cuts the third line. Apply to this distance the formula:

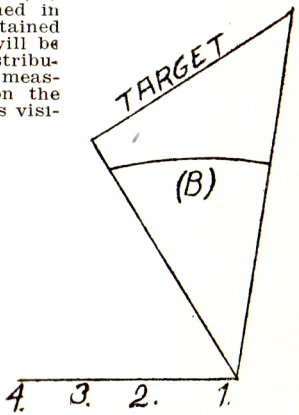
$$\frac{\text{Length of line just measured multiplied by 1000}}{\text{(Range) Battery to rear of T}} = \text{Battery angle of distribution.}$$



(A) ———— equals line to measure which on applying the formulae will give the battery angle of distribution.

(2) (i) If the target is visible from the battery position, go to the flank gun opposite the farther limit of the target.

(ii) From this point measure with the director, mils scale, or compass, the angle subtended between near and **far limit of target.** (B) (iii) Work out as in the "concentration angle" (described later) the angle subtended between the battery frontage and the near end of the target. (iv) Deduct the angle obtained in (iii) from the angle obtained in (ii). The difference will be the battery angle of distribution. (B) equals angle measured with instruments on the ground wher the target is visible.



In the foregoing examples it will be noted that the range to the target will vary between the near and far end. This is dealt with as follows:

The ranges to both ends are taken and the difference between them noted. This difference is divided by the number of gun intervals and then given out in the form of combined sights, e. g.,

Range to near end of target is 1800 yards.
Range to far end of target is 2100 yards.
Difference equals 300 yards.
Number of guns in battery, 8.
Number of gun intervals, 7.
Therefore 300 yards divided by 7 equals 43 yards.

The order, therefore, would be, assuming the target to be visible combined sights—

1800—50 yards difference.

Since, however, the target would rarely be visible, especially after a barrage starts, the order would be translated into Quadrant Elevation in mils and the same method followed.

Example:

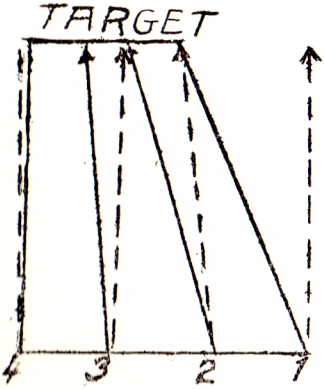
Quadrant Elevation for 1800 yards is	45.3 mils.
Quadrant Elevation for 2100 yards is	62.6 mils.
Difference is	17.5 mils.

17.5 mils divided by 7 equals 2.5 mils.

Order would be—combined elevations—45 mils, 2½ mils differences. The allowance for Angle of Site would naturally be included if necessary.

Concentration.

If the battery has to engage a target which is not so wide as the battery frontage, it is obvious that fire opened with the guns laid on parallel lines of fire would result in the bulk of the fire missing the target. (See diagram.)



Gun battery laid on parallel lines of fire or a target occupying less frontage than the battery results in fire being wasted. Heavy lines show new lines after fire is ordered to be concentrated.

To apply the fire correctly proceed as follows:

(i) Deduct the extent of target frontage from the amount of the battery frontage.

(ii) Apply formula

$$\frac{\text{Difference between Target front and Battery front} \times 1000}{\text{(Range) Battery to Target}} = \text{Mils}$$

(iii) The answer of (ii), which is called the "Battery angle of concentration," will be divided by the

number of gun intervals and the result will be the "Gun angle of concentration" for each gun.

In the above diagram, assume the following data:
Range as 2000 yards.
Target front as 20 yards.

The frontage of a 4 gun Battery, with guns at 20 yard intervals, is 60 yards. Therefore 60 yards — 20 yards equals 40 yards.

$$\text{Apply formula } \frac{40 \times 1000}{2000} = 20 \text{ mils.}$$

Number of gun intervals is 3.
20 mils divided by 3 is 6-2/3 mils.

The nearest whole number being 7 mils the order would be "No. 4 directs"—concentrate 7 mils left.

No. 4 calls out the order but does not change.
No. 3 calls out "7 mils left"—concentrate 7 mils.
No. 2 calls out "14 mils left"—concentrate 7 mils.
No. 1 calls out "21 mils left"—concentrate 7 mils.

Each gun will traverse its normal traverse that is 15 mils Right and Left of its center line, unless otherwise ordered. Battery Commanders must therefore issue orders for the extent of traverse when this differs from the normal. In this case, 5 mils left and right of center-line would be sufficient.

Where all guns are required to be concentrated on one point, the same principles as above apply; the battery frontage alone being used in the formula.

$$\frac{\text{Battery frontage} \times 1000}{\text{Range}} = \text{mils.}$$

This becomes the Battery angle of concentration and is divided between the guns in the ordinary way.

Note. In issuing orders verbally for distribution or concentration of fire; all guns are first given the angle of switch and then the angle of distribution or concentration, e. g., guns of a battery on their zero lines are required to be concentrated on a target to their right front. The order might be as follows: "all guns" —"800 mils right"—No. 4 directs—"Concentrate 10 mils" left.

Barrage Charts. In a "set piece" attack where all preparation for putting down a barrage can be made some time beforehand, the tasks alloted to each battery are recorded in detail on a chart called a "Battery Barrage Chart," and from the data recorded on these charts, are extracted the data placed on gun charts which are given to each squad leader.

A specimen chart is attached as an appendix. It will be noted on this chart that it consists of two sets of columns; in the top set are detailed the several tasks allotted to the **Battery;** in the bottom set of columns are detailed the tasks of **each gun** of the battery for each of the above tasks.

The gun chart of each gun being compiled from the battery chart and time being available to work all details out, it will be noted that in these charts, the angles of switch and distribution are shown combined. The gunner then merely lays off from his zero line the total angle given on the chart and so has given the necessary distribution or concentration.

Section "C"

Use of Instruments

CONTENTS

Instruments

Instruments are required for obtaining, putting on and maintaining direction and elevation when firing indirect.

DIRECTION DIAL. The tripod is fitted with a direction dial graduated in mils from 0 to 6400.

The outer edge is adjustable, so that the zero mark may be readily adjusted when the gun is laid for direction on its zero line. The dial should be kept permanently attached to the tripod. Care should be taken of the dial, both to prevent actual deformation due to rough usage, and also, as far as possible, to prevent the scale becoming obliterated.

THE COMPASS. The compass is the basis used for putting on and finding direction. The model used by the machine gun officer must be a good instrument, either prismatic or its equivalent. It must be fitted with a luminous dial and capable of being adjusted and accurate readings taken at night.

The error of each compass must be determined; its magnitude and sign must be recorded.

The following test may be used:

From an accurate map select two points, both easily determinable on the ground and reasonably far apart. Join these points on the map, and, by knowing the magnetic variation, determine the magnetic bearing from one to the other.

Proceed to the ground and read the bearing indicated by the compass under trial from one point to the other several times. The mean of these readings should agree with the magnetic bearing obtained from the map. If it does not agree, the difference between them is the error of the compass, either too high or too low, as the case may be.

This error must be allowed for in all calculations that involve the use of this instrument.

The compass is used by the machine gun officer for resection or for obtaining and putting on direction.

It should not be used when close to steel or iron.

The gun, tripod (unless the compass tower is used), spare parts, etc., should be removed, and the user should not have metal on his person, such as revolver or steel helmet.

PROTRACTOR. Is an instrument for measuring angles and ranges on a map. It is used for finding the angles subtended by any two points at a third. The co-ordinate of any given point may also be found.

It is usually semi-circular in shape and made of

transparent celluloid, and about 3 inches in radius. The angular measurement should be shown in mils.

INFANTRY RANGE FINDER. Bausch & Lomb, 80 C. M. Fixed Base. Directions for Using the Range Finder. Rotate shutters on the objective openings to permit light to enter the instrument. Train the instrument on the object to be measured and carefully focus the eyepiece. The field of vision is bisected by a narrow horizontal strip, in which is seen the inverted image.

The range scale is visible directly below the lower edge of the horizontal strip. Always use the lower edge when making a coincidence. To bring about a coincidence swing the instrument in a horizontal plane about its vertical axis until the two images are in perfect alignment. Then read the scale directly below the point where the alignment is perfected. When the target to be measured is wide, make the coincidence, using only one side of the target, and read the scale directly below the point where the outlines of the two images coincide.

Adjustment of Range Finder. 1. When the images in the range finder are not symmetrically placed with respect to the line of separation, it is designated as a halving error. This may be at once recognized by the fact that when a prominent point in the erect image is made to touch the line of separation, the corresponding point in the inverted image is either some distance above the line or else vanishes below it.

To eliminate this defect push back the slide, marked "Halving Adjuster," which exposes a milled roller. Turn this roller until the images occupy the correct position and move the slide back to its former position.

2. To correct the instrument for range reading, select a target of known distance, preferably one at about 1000 meters. Carefully focus the eyepiece so that the images appear sharp and bring about a coincidence in the usual way. If the range obtained is not the same as the actual distance, place the milled key which operates the Correction Wedge on the square shank. Turn this key about one quarter turn and observe whether or not the images coincide at the proper place on the range scale. Should the range error increase when doing this, turn the key in the opposite direction until the desired result is obtained. If the instrument has been corrected for any one distance, all other measurements will be correct.

It should be clearly borne in mind that while these range finders are instruments of the highest precision, in order to secure the exact results which they are capable of giving, the observers should be carefully and fully trained in their practical use, otherwise the best of results will not be secured.

ANGLE OF SITE INSTRUMENT. When working in country where the contours on maps are inaccurate, or do not exist, and on occasions where the positions of gun and target cannot be accurately located, the angle of site instrument must be used to obtain the necessary firing data for obtaining elevation.

The accuracy of the instrument must be tested and any known errors and allowances made in the readings.

SPIRIT LEVEL. The spirit level (or Clinometer, fitted with a spirit level) forms the basis of all indirect fire, except when the inverted rear sight method is used.

A spirit level cannot be adjusted, but its correctness should be checked by comparing it with a clinometer known to be correct. The error, if any, when determined, should be marked on the spirit level. This error will vary according to how the level is placed on the gun, so that in determining the error, the end nearest the firer should be noted and unmistakably marked with a spot of luminous paint.

When applying the level, but not during reading, the gun should be gently tapped with the hand on the top of the barrel casing (not pressed) so as to shake the level slightly and assist the bubble in taking its true position.

The angle between the surface upon which it is placed and the axis of the bore must be determined for each gun and recorded.

The following method should be used:

1. Use a clometer of known error.
2. Take two points about 500 yards apart on the ground which have been determined by surveying instruments to be on the same level.
3. Mount the gun at one of these points and, with the gun approximately level, measure the height of the center of the bore at the muzzle above the point selected.
4. Place a bullseye target of sufficient size to be clearly seen at this range, with the lowest edge at a similar height above the point as that determined in No. 3.
5. Remove the recoiling portions from the gun and replace the barrel and lay the gun by sighting through the barrel on this bull, insuring that the center of the bore is at the bottom of the bullseye target.

6. Place the clinometer on the gun; if it does not read zero, adjust the clinometer until the bubble is centered. The reading on the scale gives the difference required.

THE CLINOMETER. This istrument forms part of the equipment of a gun squad and is the basis used for putting on elevation in indirect fire. It is graduated in mils. It should be tested for accuracy by comparing it with one known to be in adjustment. In the field this test may usually be carried out by application to the artillery. The greatest care should be taken to guard against damage.

AUXILIARY AIMING MARKS. (An auxiliary aiming mark is any object other than the target on which the sights are aligned so the cone of fire will strike the target.)

a. **ZERO AIMING POST.** This is a post about 2' 6" long, shod with an iron spike and bound with iron at the top. It should be made of sound wood and be about 2" in diameter, or metal ½-inch piping. It should be painted black and white in alternate rings to be readily distinguished from the surrounding landscape.

b. **"T" AIMING POST.** This is used to assist the gun numbers in laying off small angles from a line of fire and to check the traverse and laying.

c. **NIGHT FIRING BOX.** This is a box fitted with a suitable transparent material which will allow light to pass through it without blurring the aim of the firer. It should only allow the light to be thrown in one direction.

d. **IMPROVISED A. A. M.** Any suitable object may be selected as an auxiliary aiming mark.

SLIDING GRAPH. To Obtain QE. The vertical arcs on the graph represent range, the horizontal lines height of target above or below gun (in metres). Find range and VI from map. Adjust slide so that the centre shot line passes exactly through intersection of arc representing range, and line representing VI. (This can be judged for intermediate ranges and VI's.) Without moving the slide see where the centre shot line cuts the graduated scale marked on the gun level (or the auxiliary one at the bottom of the graph). This gives required QE in mils. to hit target.

To Obtain Clearance. Find position on graph of friendly troops. If it comes below the danger line, it is safe to fire; if above, it is unsafe. Exact clearance (in metres) may easily be read off on graph. Highest and lowest shots are marked on slide and can be used for judging size of cone, clearance over obstacles, etc.

Section "D"

ORDERS

CONTENTS

Fire Orders

In order to maintain fire control, fire discipline, and the result of both, i. e., maximum fire effect, it is absolutely necessary that officers and men receive thorough training in the issue and execution of fire orders. It is appalling how many officers cannot give a fire order properly and how many men cannot carry into execution a fire order which is given properly.

You cannot expect maximum results when the men are poorly trained or the fire order is improperly given.

The execution of fire orders involves a thorough training in visual training, military vocabulary and designation and recognition of targets. It is essential that unformity of method be maintained. The number of guns to which a verbal fire order can be given direct is limited to the carriage of the voice. Usually, this number will not exceed four.

Orders may be issued as follows:

1. Direct to the firer when the controlling officer is close to his guns.

2. On occasions where the target cannot be clearly designated, it may be found necessary and quicker for the controlling officer to lay the guns himself.

3. The orders may also be issued indirectly to the guns, through subordinates, either verbally or by written messages.

The position of the fire unit commander should be carefully selected with a view of obtaining:

a. Observation of his fire.
b. Observation of his own troops.
c. Observation of the enemy.

The method to be followed in giving fire orders is as follows:

The fire order must be given as an **order, not as a request.** This will give the firers confidence, and will assist them in carrying out the order accurately. It must be given clearly, calmly, concisely, with pauses, and in a sufficiently loud tone of voice to be understood. In order to insure that the firer understands the order given, all fire orders will be repeated by him.

A definite sequence in the issue of an order must be followed. The range must be given first; deflection; the target indicated next; then the type of fire to be applied; followed by the signal to fire. It is the duty of "Number Two" at the gun to watch for

signals at all times and to communicate these signals to No. 1.

In order to issue a good fire order, the officer must bear in mind the following points:

He must consider the tactical situation, the method of obtaining the range, the atmospheric conditions of the moment, and he must rapidly decide how he is going to describe his target and what type of fire he is going to employ in order to obtain maximum results.

He must be conversant with the methods of fire and firing data.

His fire order must be as short as possible consistent with clearness; brevity and clearness are essential. Examples:

1. 1000.
2. Right 2.
3. Machine gun.
4. Fire (fixed fire is understood).

1. 1000.
2. No deflection.
3. Barn to Creek.
4. Inward Traversing.
5. Fire.

1. 1000.
2. Left 4.
3. Machine gun.
4. Search up and down 2 mils.
5. Fire.

System	Example
1. Announce range.	1. 1000.
2. Announce direction of the reference point.	2. Reference point at 2 o'clock.
3. Designate reference point.	3. A stone house with two chimneys.
4. Announce target with respect to reference point.	4. Target at 3 o'clock.
5. Announce objective.	5. Machine gun.
6. Fire.	6. Fire.

Procedure

(1) Men set sights at 1,000 meters.
(2) All men look to their right front (or along 2 o'clock line).
(3) The reference point (stone house) is found in the indicated direction.
(4) Unless stated otherwise, a clock face (vertical) is imagined centered on the highest point of the reference object, and the men look along the line leading from the clock center through 3 o'clock and—
(5) Find machine gun at 1,000 meters from the firing point.
(6) Fire.

Secret. FIELD ORDERS NO. 1.

Reference Map Camp Lewis, No. 4.

Hdqrs. Co. "B," 38th M. G. Bn.
Camp Lewis, Washington.
22nd March, 1918, 7:30 P. M.

1. (Any information necessary about enemy.)

2. This company will relieve the "A" Company, 39th Machine Gun Battalion in the CAMP LEWIS trench sector on the night of 23/24 March, 1918.

3. (a) Our 1st Platoon will relieve the 1st Platoon, Company "A" in.....trench. Gun positions as follows: (Give map reference). Platoon Headquarters will be (Give map reference).

(b) Our 2nd Platoon will relieve the 2nd Platoon, Company "A" in.....trench. Gun positions as follows: (Give map references). Platoon Headquarters will be (Give map reference).

(c) Our 3rd Platoon will relieve the 3rd Platoon, Company "A" in the.....trench. Platoon Hdqrs. will be (Give map reference). Gun positions as follows: (Give map reference).

The company fully equipped will be formed at 7:45 P. M. March 23rd, 1918, with carts packed and rations for gun squads for one day.

The company will march at 8:00 P. M. by platoons in the order 1st, 2nd and 3rd, maintaining a distance of 200 yards between platoons. Carts of each Platoon to follow in rear of its platoon.

Carts will halt in succession and be unpacked on trail crossing BEEF CREEK at (Give map reference).

The advance from Beef Creek will be by Squads. Suitable distances being maintained between each squad.

Guides from Company "A" will meet reliefs at BEEF CREEK crossing and pilot them to advanced company headquarters.

Guides will be awaiting at advanced company headquarters for each squad and conduct them to their appointed posts.

Ammunition boxes and trench stores will be carefully checked and receipts given.

Firing program will be taken over and continued. Programs of work will be carried on.

"Relief Complete" will report to advanced company headquarters by most direct means.

4. Advanced company headquarters will be (Give map reference). Rear Company headquarters will remain at this point.

JOHN SMITH,
Captain Commanding Co. B.

Acknowledge receipt.

Copies—

No. 1. Platoon Leader 1st Platoon Co. B.
No. 2. Platoon Leader 2nd Platoon Co. B.
No. 3. Platoon Leader 3rd Platoon Co. B.
No. 4. Officer in charge combat train.
No. 5. Second in command.
No. 6. File Personal.
No. 7. Commanding Officer Co. A.
No. 8. Commanding Officer M. G. Co. on right.
No. 9. Commanding Officer M. G. Co. on left.
No. 10. Brigade Headquarters.
No. 11. War Diary.
No. 12. War Diary.
No. 13. Company File (Kept on rear Co. hdqrs.)
No. 14. Commanding Officer M. G. Battalion.

ORDERS FOR SENTRY AND GUN TEAM COMMANDERS AT MACHINE GUN POSITION NO. .....

1. Fire is to be opened by order of the Gun Commander, unless a sudden emergency arises, in which case the sentry will use his own initiative.

2. When relieving another Gun Team or Sentry, the following facts will always be ascertained:

(a) Whether gun has been fired during the relief.
(b) If fired, what was the target?
(c) From what position was it fired?
(d) Whether any instructions have been received as to friendly patrols or wiring parties.
(e) Whether enemy machine guns have been firing in the vicinity, if so, their probable direction.
(f) Whether any hostile shelling has occurred near the gun position which might indicate that it had been located by the enemy.
(g) Whether there have been any movements of our own or hostile aircraft.
(h) Whether any unusual point or sound has been observed.
(i) Positions and lines of fire of neighboring guns.

3. The sentry will always inspect the gun when taking over the position.

4. The sentry on duty must have an accurate knowledge of the points shown on the Range Card.

5. In case of an **alarm** or **gas attack**, the sentry will warn the Gun Team immediately.

6. The gun will not usually be mounted in position, except during the hours of darkness or unless the situation renders it advisable.

7. The gun will be cleaned daily, and the **points before firing** gone through both morning and night. The gun must be kept free from dirt and, in the trenches, must be wrapped up in a waterproof sheet or bag. Such a covering must not prevent the gun being mounted for action immediately.

8. Ammunition, spare parts and anti-gas apparatus will be inspected daily.

The sentry will be responsible that all anti-gas apparatus is in position and in order.

9. The driving (main or lock) spring will never be left compressed. (With the Vickers gun it is generally sufficient to half-load and then press the thumb piece, when mounting the gun at night. If ordered to open fire, it is only necessary to complete the loading motion and press the thumb piece.)

10. All dug-outs, emplacements and ammunition recess belonging to the gun position must be kept clean and in good repairs.

SPECIAL ORDERS FOR THIS GUN POSITION

11. The S. O. S. signal is: 12. Action on S. O. S.

13. Action if enemy penetrates front line.

.....

Date..... Machine Gun Officer.

Section "E"

GENERAL SUBJECTS

CONTENTS

MIL SYSTEM

A mil is an angular measurement (approximately three minutes of arc) whose tangent is 1/1000 of the radius. In other words, 1 mil will cover at 1,000 yds. 1 yd. intercept, 50 mils will cover 50 yds. or 1/20 of the range. If a 50 yd. trench is placed parallel to a position at a point of 1000 yds. away and a mil scale held up, 50 mils will just cover the trench. A mil scale can easily be made by reproducing the graduations of a ruler showing inches divided into tenths and held 20 inches from the eye.

USE OF MIL SCALE FOR RANGE DETERMINATION

(1) $R = \frac{W \times 1000}{M}$ R=range in yds.

(2) $W = \frac{R \times M}{1000}$ W=width or height in yds.

(3) $M = \frac{W \times 1000}{R}$ M=number of mils.

ANGLE OF SIGHT FORMULAE

In all forms of indirect fire (except the inverted sight system) it is necessary to determine the quadrant elevation, which is a combination of the angle of site and the angle of departure.

Calculations can be dispensed with when tables, graphs or the Fire Control Rule are available.

1. It can be calculated when maps show the contours by:

$$\text{Mils} = \frac{\text{Width} \times 1000}{\text{Range}}$$

when width and range are the same unit (metres, yards, feet, etc.)

2. It can be measured by an angle of sight instrument.

3. Also by the gun directly, by first levelling the gun and noting the reading on the elevating dial, and then recording the angle passed through when laying on the target, or desired object. The sights, of course, being at zero.

4. The tangent sight can also be employed by:

i. Levelling the gun; with sights at zero, note where the line of sight is pointing; then lay on the target if it is above the gun. If, then, the slide is adjusted until the line of sight is directed on to the spot originally noted, the angle of sight will be found to be the angle for the equivalent range (See Angle of Departure Table).

ii. If the target is below the gun, the gun should be first "levelled" and then the slide only should be moved until the line of sight is directed on the object, when the angle of sight is the angle for the equivalent range.

The angle of sight is POSITIVE when the target is above the gun and NEGATIVE when below.

POSITIVE angles are added to the Angle of Departure.

NEGATIVE angles are deducted from the Angle of Departure.

RE-SECTION AND LOCATION OF POSITIONS ON THE MAP

Of the various methods for locating, on the map, one's position on the ground, the following are suitable:

1. **By Re-Section.**

i. This is useless when the map itself is inaccurate.

ii. Unnecessary when the map is accurate in detail, and the position to be located is near any object which it is possible to identify, both on the map and on the ground.

iii. Necessary when the map is accurate in detail, but when the position to be located is NOT near any object which can be identified both on the map and on the ground.

To Locate a Point by Re-Section

(a) Select two points on the ground which are marked on the map, and on which compass bearings can be taken.

(If possible select points approximately at right angles.)

(b) Using a prismatic compass, determine the magnetic bearings of these points, convert to grid bearings, and then on the map lay out back bearings from the corresponding points on the map. (Compass error must be allowed for.)

(c) These back bearings will intersect at a point which, if the compass and map are accurate, will be the required position.

NOTE—Three points may be used instead of two. In this case, if the three back bearings do not all pass through one point on the map, they will form a triangle.

If this triangle is LARGE, either the compass is inaccurate and should be tested, or the work is inaccurate and should be repeated, or the map is inaccurate, in which case nothing can be done.

If the triangle is SMALL, two cases may arise:

(a) Where the small triangle falls INSIDE the triangle formed by joining the three points to which bearings were taken.

In this case the actual position may be taken as at the center of the small triangle.

(b) Where the small triangle falls OUTSIDE the triangle formed by joining the three points to which bearings were taken.

In this case the procedure is more difficult, and the point can only be found by estimation, using the following rules:

The point will be outside the small triangle; it will be either to the right or to the left of all the rays, looking towards the three points to which bearings were taken, and it will be nearest to that side which is formed by the shortest ray.

Its exact position is determined by the condition that its respective distance from the rays must be proportional to the lengths of the rays themselves.

Whenever three points are being used, try and get them approximately 120 degrees apart, so as to get condition (a) above and avoid the difficult case (b).

2. By Compass and Range Finder

It may happen that one object only can be identified both on the map and on the ground. In this case a position may be determined by taking the bearing of that object, and the range to it.

On the map, lay out a back bearing from the object, and measure back a distance to the map scale corresponding to the range found. This will locate the position.

ARM SIGNALS FOR CONTROLLING FIRE

Action: Strike with closed fist in direction indicated. This signal is used to put guns into firing positions as described in par. 664.

Out of Action: Strike the open palm of one hand with the closed fist of the other hand. (Signal indicates gun is out of action or not ready to fire.)

Range or change elevation: To announce **range** extend the arm toward the leaders or men for whom the signal is intended, fist closed; by keeping the fist closed battle sight is indicated; by opening and closing the fist, expose thumb and fingers to a number equal to the hundreds of yards; to add 50 yards describe a short horizontal line with the forerfinger. **To change elevation** the fire controller indicates the new range. The fire observer indicates the amount of increase or decrease by pointing upward for increase, downward for decrease, and exposing the number of fingers.

What range are you using? or **What is the range?** Extend the arms toward the person addressed, one hand open, palm to the front, resting on the other hand, fist closed.

Are you ready or **I am ready:** Raise the hand, fingers extended and joined, palm toward the person addressed.

Commence firing: Move the arm extended in full length, hand palm down, several times through a horizontal arc in front of the body.

Fire faster: Execute rapidly signal "Commence firing."
Fire slower: Execute slowly signal "Commence firing."

Suspend firing: Raise and hold the forearm steadily in a horizontal position in front of the forehead, palm of the hand to the front.

Cease firing: Raise forearm as in **suspend firing.** and swing it up and down several times in front of the face.

Distributed or **traversing fire:** Extend arm to the front, palm to the left, and wave the hand up and down with a chopping motion, at the same time moving the hand and arm from right to left, or left to right, as it is desired that the fire be distributed.

Searching fire, —— mils up: Extend arm to the front, describe a vertical circle in front of the body, the arm extended. Indicate mils in **Up mils.**

Searching fire, —— mils down: Extend arm to the front, describe a vertical circle in front of the body. Indicate mils.

To swing cone of fire to the right or left: Extend the arm in full length to the front, palm to the right (left); swing the arm to right (left), and point in the direction of the new target.

Up —— mils: Extend the arm downward, with palm to the front, and wave upward with a full swing of the arm. Indicate number of mils by thrusting closed fist to the front once for each 5 mils, and upward once for each single mil. Thus for 6 mils thrust to the front once and upward once.

Down —— mils: Extend arm to the front, palm down, and wave downward. Indicate number of mils by thrusting closed fist to the front once for each 5 mils, and downward once for each single mil.

To right —— mils: Extend arm to the front and wave to the right. Indcate mils as in Up.

To left —— mils: Same as above, substituting **left** for **right.**

37. For communication between the firing line and the reserve or commander in the rear, the subjoined signals are prescribed and should be memorized. In the absence of signal flags, the headdress or other substitute may be used. In transmission of signals their concealment from the enemy's view should be insured.

TACTICAL HINTS FOR A COMPANY COMMANDER ON GOING INTO THE "LINE"

Tactics

Ascertain the tactical situation.

Ask for the battle map, which should show arcs of fire, battle emplacements, anti-aircraft emplacements, S. O. S. lines, alternative emplacements, harassing emplacements, etc.

What are the "break through" guns? The S. O. S. guns? Anti-aircraft guns?

What are the dispositions of the infantry?

How are the Lewis guns disposed in the scheme of defense?

Where are the various H. Q. (Brigade and Bn. and Co.)?

What is the S. O. S. signal?

Can all the guns be visited by daylight?

What work is in progress?

When is the best time to relieve?

Where are the guides to meet us?

Comfort

What is the dug-out accommodation?

What are the arrangements for water?

What are the arrangements for cooking?

When is the best time to get rations up?

Section "F"

FORMS

CONTENTS

EMPLACEMENT OR DUGOUT INVENTORY Board No._____

ITEMS	NUMBER ON HAND									
Picks										
Shovels										
Axes										
Belt Boxes										
Ammunition Boxes										
Periscopes										
Gas Screen										
Grenades, Hand										
Very Pistols										
Very Lights										
Refuse Tin										
Fighting Map										
Barrage Chart										
Intelligence Summary										
Signature and Organization										

THE INFANTRY SCHOOL OF ARMS

Fire Calculations Form—(*Provisional*)

(Indirect or indirect overhead fire)

All distances and contours in yards—meters
(Erase word not applicable)

Organization_____ Date_____ Map used_____ Officer in charge of firing_____

ELEVATION									CLEARANCE OVER OWN TROOPS						DEFLECTION	REMARKS	CHECKED
Gun No. and Map Location	Target and Map Location	Range to Target	Contours At Gun	Contours At Target	Vertical Interval	Angle of Site (mils)	Angle of Departure for Range (mils)	Quadrant Elevation (mils) A	Distance to Own Troops	Contour at Position of Own Troops	Vertical Interval to Own Troops	Angle of Site to Own Troops (mils) 3					
									Nearest								
									Farthest								
									Nearest								
									Farthest								
									Nearest								
									Farthest								
									Nearest								
									Farthest								
									Nearest								
									Farthest								
									Nearest								
									Farthest								

NOTES: 1—Angle of clearance in mils=A—B.
2—Immediately before firing make allowance for climatic conditions.
3—If problem is clearance of mask only, then A must exceed the Quadrant Elevation to mask [illegible] the depth of the cone (in mils)

Form No. 216–5-2

F-2

BATTERY BARRAGE CHART

Map..... .....BATTERY Place.....

Battery frontage ..... Date.....

Grid bearing of zero lines.....

Composition ..... Method of laying out zero lines

TASKS

Commanded by..... ..... A .....

Location of Directing Gun..... ..... B .....

Number of Directing Gun..... ..... C .....

Task	Guns	Target	Clock Time	Zero Time	Battery Angle of Switch	Target Frontage	Angle of Distribution	Range	V. I.	Q. E.	Traverse Per Gun

Task	GUN ANGLES FROM ZERO LINE								GUN ELEVATIONS							
	No. 8	No. 7	No. 6	No. 5	No. 4	No. 3	No. 2	No. 1	No. 8	No. 7	No. 6	No. 5	No. 4	No. 3	No. 2	No. 1

F-53

GUN CHART FOR BARRAGE.

Number_____Gun. Number_____Battery_____Gun Commander

Grid bearing of Zero Line_____Mils. Magnetic Bearing Zero Line_____Mils.

Task	Clock Time	Zero Time	ANGLE OF DEVIATION From Zero in Mils (Right (R) / Left (L))	Q. E. or Angle of Fire in Mils	Rate of Fire	Traverse in Mils

F-4

CONCENTRATION POINTS

No. of Point	Angle of Deviation from Zero in Mils	Q. E. or Angle of Fire in Mils	REMARKS

S. O. S. Call_____

Date_____ _____ _____

Signature Battery Commander

Squad No.....

MACHINE GUN DEPARTMENT INFANTRY SCHOOL OF ARMS, 13TH DIVISION

DAILY RECORD OF GUN

Camp Lewis, Wn.,.....1918.

Gun No.....

Barrel No.....

Parts missing .....

Parts damaged.....

Parts broken .....

Parts replaced.....

Cause .....

Tripod No.....

Remarks .....

.....

Instructor.....

M. G. FIRE ORGANIZATION ORDERS

PLACE

Map----------

Date of Issue

Group	Commander	Batteries	Composition of Batteries	Approximate Position	TASKS	No. of Guns	Zero Time	Rate of Fire	REMARKS

Signature----------

Commanding M. G. Bn.

Section "G"

TABLES

CONTENTS

ANGLES OF DEPARTURE OF BROWNING MACHINE GUN

Based on Experimental Firing at Springfield Armory during September 1918. U. S. Cal. 30—Model 1906—150 grain bullet.

Range	Angles of Departure	Remarks
Meters	Mils	
100	.8	The **average** jump is found experimentally, to be —.5 mils. Hence the **average** angle of elevation will be the angle of departure, as given in this table, plus 0.5 mils.
200	1.7	
300	2.7	
400	3.9	
500	5.3	
600	6.9	Because of unavoidable variations in quantity production, however, the **actual** angles of elevation must be determined experimentally for each gun by the troops to whom it is issued.
700	8.8	
800	11.0	
900	13.6	
1000	16.6	
1100	20.1	
1200	24.3	
1300	29.1	
1400	34.6	
1500	40.8	
1600	47.8	
1700	55.6	
1800	64.5	
1900	73.7	
2000	84.0	
2100	95.8	
2200	109.7	
2300	127.3	
2400	151.5	
2500	182.3	
2600	219.5	

DISPERSIONS OF THE BROWNING MACHINE GUN

(Computed from data obtained by experimental firing at Springfield Armory and at the Infantry School of Arms, U. S. cal. 30 Model 1906—150 grain bullet.)

Range	Vertical—Dispersion				Lateral—Dispersion				Longitudinal—Dispersion	
	100% Zone		75% Zone		100% Zone		75% Zone		100% Zone	75% Zone
Meters	Meters	Mils	Meters	Mils	Meters	Mils	Meters	Mils	Meters	Meters
100	.52	5.16	.17	1.72	.22	2.20	.08	.77	From muzzle to 358 meters	From muzzle to 194 meters
200	1.03	5.16	.34	1.72	.44	2.20	.15	.77	426 "	179 "
300	1.55	5.16	.52	1.72	.68	2.27	.24	.80	484 "	161 "
400	2.06	5.16	.69	1.72	.91	2.28	.32	.80	414 "	138 "
500	2.58	5.16	.86	1.72	1.15	2.30	.40	.81	355 "	118 "
600	3.10	5.16	1.03	1.72	1.38	2.30	.48	.81	301 "	100 "
700	3.61	5.16	1.20	1.72	1.62	2.31	.57	.81	262 "	87 "
800	4.13	5.16	1.38	1.72	1.86	2.33	.65	.82	219 "	73 "
900	4.72	5.24	1.57	1.75	2.10	2.33	.74	.82	188 "	63 "
1000	5.37	5.37	1.79	1.79	2.38	2.38	.84	.84	166 "	55 "
1100	6.12	5.56	2.04	1.35	2.63	2.39	.92	.84	146 "	49 "
1200	7.00	5.83	2.33	1.94	2.94	2.45	1.03	.86	130 "	43 "
1300	8.20	6.31	2.73	2.10	3.31	2.55	1.16	.89	123 "	41 "
1400	9.71	6.94	3.24	2.31	3.78	2.70	1.33	.95	119 "	40 "
1500	11.45	7.63	3.82	2.54	4.36	2.91	1.53	1.02	116 "	39 "
1600	13.46	8.41	4.49	2.80	5.08	3.18	1.78	1.12	114 "	38 "
1700	15.83	9.31	5.28	3.10	5.94	3.49	2.08	1.23	112 "	37 "
1800	18.24	10.13	6.08	3.38	6.90	3.83	2.42	1.35	112 "	37 "
1900	21.05	11.07	7.02	3.69	7.98	4.20	2.80	1.47	114 "	38 "
2000	25.11	12.55	8.70	4.18	9.22	4.61	3.24	1.62	114 "	38 "
2100	30.60	14.57	10.20	4.86	10.74	5.11	3.77	1.80	114 "	38 "
2200	39.31	17.87	13.10	5.96	12.60	5.73	4.42	2.01	115 "	38 "
2300	54.93	23.88	18.31	7.96	15.00	6.52	5.27	2.29	117 "	39 "
2400	77.52	32.30	25.84	10.77	18.28	7.62	6.42	2.67	119 "	40 "
2500	101.66	40.66	33.89	13.55	22.94	9.17	8.03	3.21	122 "	41 "
2600	130.00	50.00	43.33	16.67	29.73	11.43	10.41	4.00	134 "	45 "

ORDINATES OF THE TRAJECTORY OF THE BROWNING MACHINE GUN IN METERS.

Based on Experimental Firing at Springfield Armory during September, 1918—U. S. Cal. .30—Model 1906—150 grain bullet.

Minus Ordinates above Zero. Plus Ordinates below Zero.

Angle of Depart.	Range Meters	Horizontal Distance—Meters.																									
		100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600
.8	100	**0**	.18	.57	1.24	2.25	3.66	5.6	8.16	11.52	15.8	21.26	29.2	36.79	47.32	60.	75.2	93.16	114.66	138.51	166.4	199.71	239.58	290.95	361 68	453.75	568.62
1.7	200	.09	**0**	.30	.88	1.8	3.12	4.97	7.44	10.71	14.9	20.24	27.12	35.62	46.06	58.65	73.76	91.63	113.04	136.8	164.6	197.61	237.6	288.88	359.52	451.5	566.28
2.7	300	.19	.20	**0**	.48	1.3	2.52	4.27	6.64	9.81	13.9	19.14	25.92	34.32	44.66	57.15	72.16	89.93	111.24	134.9	162.6	195.51	235.4	286.58	357.12	449.	563.68
3.9	400	.31	.44	.36	**0**	.7	1.8	3.43	5.68	8.73	12.7	17.82	24.48	32.76	42.98	55.35	70.24	87.89	109.08	132.62	160.2	192.99	232.76	283.82	353.76	446.	560.55
5.3	500	.45	.72	.78	.56	**0**	.96	2.45	4.56	7.47	11.3	16.28	22.6	30.94	41.02	53.25	68.	85.51	106.56	129.96	157.4	190.05	229.68	280.60	350.88	442.5	556.92
6.9	600	.61	.84	1.26	1.20	.8	**0**	1.33	3.28	6.03	9.7	14.52	20.88	28.86	38.78	50.85	67.04	82.79	103.68	126.92	154.2	186.69	226.16	276.92	347.04	438.5	552.76
8.8	700	.8	1.42	1.83	1.96	1.65	1.14	**0**	1.76	4.32	7.8	12.43	18.6	26.39	36.12	48.	62.4	79.56	100.26	123.31	150.4	182.7	221.98	272.55	342.48	433.75	547.82
11.0	800	1.02	1.86	2.49	2.84	2.85	2.46	1.54	**0**	2.34	5.6	10.01	15.96	23.53	33.04	44.7	58.88	75.82	96.3	119.13	146.	178.08	217.14	266.80	337.2	428.25	542.1
13.6	900	1.28	2.38	3.27	3.88	4.15	4.02	3.36	2.08	**0**	3.	7.15	12.84	20.15	29.4	40.8	54.72	71.4	91.62	114.19	140.8	172.62	211.42	261.51	330.96	421.75	535.34
16.6	1000	1.58	2.98	4.17	5.08	5.65	5.82	5.46	4.48	2.7	**0**	3.85	9.24	16.25	25.2	36.3	49.92	66.3	86.22	108.49	134.8	166.32	204.82	254.61	323.76	414.25	527.54
20.1	1100	1.93	3.88	5.22	6.48	7.4	7.92	7.91	7.28	5.85	3.5	**0**	5.04	11.7	20.3	31.05	42.72	60.35	79.92	101.84	127.8	158.97	197.12	246.56	315.36	405.5	518.44
24.3	1200	2.35	4.52	6.48	8.16	9.5	10.44	10.85	10.64	9.63	7.7	4.62	**0**	6.24	14.42	24.75	37.6	53.21	73.36	93.86	119.4	150.52	187.88	236.9	305.28	395.	507.52
29.1	1300	2.83	4.48	7.92	10.08	11.9	13.32	14.21	15.28	13.95	12.5	9.9	5.76	**0**	7.7	17.55	29.92	45.05	63.72	83.74	109.8	137.97	177.32	225.86	293.76	383.	495.04
34.6	1400	3.38	6.58	9.57	12.28	14.65	16.62	18.06	18.88	18.9	18.	15.95	12.36	7.15	**0**	9.3	21.12	35.7	53.82	74.29	98.8	128.52	165.22	213.21	280.56	369.25	480.74
40.8	1500	4.	8.02	11.43	14.76	17.75	20.34	22.4	23.84	24.48	24.2	22.77	19.8	15.21	8.68	**0**	11.2	25.16	42.66	62.51	86.4	115.5	151.58	198.95	265.68	353.75	464.62
47.8	1600	4.7	9.22	13.53	17.56	21.15	24.54	27.3	29.44	30.78	31.2	30.47	28.2	24.31	18.48	10.5	**0**	13.26	30.06	49.21	72.4	100.8	136.18	182.85	248.88	336.25	446.42
55.6	1700	5.48	10.78	15.89	20.68	25.15	29.22	32.76	35.68	37.8	39.	39.05	37.56	34.45	29.4	22.2	12.48	**0**	16.02	34.29	56.8	84.42	119.02	164.91	230.16	316.75	426.14
64.5	1800	6.37	12.56	18.54	24.24	29.6	34.56	38.99	42.8	45.81	47.9	48.84	48.24	45.02	41.86	35.55	26.72	15.13	**0**	17.48	39.	65.73	99.44	144.44	208.8	294.5	403.
73.7	1900	7.29	14.4	21.3	27.92	34.2	40.08	45.43	50.16	54.09	57.1	58.96	59.28	57.98	54.74	49.35	41.44	30.77	16.56	**0**	20.6	46.41	79.2	123.28	186.72	271.5	379.08
84.0	2000	8.32	16.46	24.39	32.04	39.35	46.26	52.64	58.4	63.36	67.4	70.29	71.64	71.37	69.16	64.8	57.92	48.28	35.10	19.57	**0**	24.78	56.54	99.59	162.	245.75	352.3
95.8	2100	9.5	18.82	27.93	36.76	45.25	53.34	60.9	67.84	73.98	79.2	83.27	85.8	86.71	85.68	82.5	76.8	68.34	56.34	41.99	23.6	**0**	30.58	72.45	133.68	216.25	321.62
1 09.7	2200	10.89	21.6	32.1	42.32	52.2	61.68	70.63	78.96	86.49	93.1	98.56	102.48	104.78	105.14	103.35	99.04	91.97	81.36	68.4	51.4	29.19	**0**	40.48	100.32	181.5	285.48
1 27.3	2300	12.65	25.12	37.38	49.36	61.	72.24	82.95	93.04	102.33	110.7	117.92	123.6	127.66	129.78	129.75	127.2	121.89	113.04	101.84	86.6	66.15	38.72	**0**	58.08	137.5	239.72
1 51.5	2400	15.07	29.96	44.64	59.04	73.1	86.76	99.89	112.24	124.11	134.9	144.54	152.64	159.12	163.66	166.05	155.92	163.03	156.60	147.82	135.	116.97	91.96	55.56	**0**	77.	176.8
1 82.3	2500	18.15	36.12	53.88	71.36	88.5	105.24	121.45	137.04	151.83	165.7	178.42	189.6	199.16	206.78	212.25	215.2	215.39	212.04	206.15	196.6	181.65	159.72	126.50	73.92	**0**	96.72
2 19.5	2600	21.87	43.56	65.04	86.24	107.1	127.56	147.49	166.8	185.31	202.9	219.34	234.24	247.52	258.86	268 05	274.72	278.63	279.	277.02	271.	259.77	241.56	212.06	163.20	93.	**0**

QUADRANT ANGLE IN MILS KNOWING RANGE AND V. I. (Both in Meters.)

TARGET ABOVE GUN.

Based on Experimental Firing at Springfield Armory during September, 1918—U. S. Cal. .30—Model 1906—150 grain bullet.

V.I.	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600
1	10.	5.	3.3	2.5	2.	1.6	1.4	1.2	1.1	1.	.9	.8	.75	.7	.65	.625	.59	.55	.5	.5	.45	.45	.4	.4	.4	.4
5	50.8	26.7	19.4	16.4	15.3	15.2	15.9	17.3	19.2	21.6	24.6	28.5	32.9	38.2	44.1	50.9	58.5	67.3	76.3	86.5	98.2	112.0	129.5	153.6	184.3	221.5
10	100.8	51.7	35.7	28.9	25.3	23.5	23.1	23.5	24.7	26.6	29.2	32.4	36.8	41.7	47.5	54.0	6115	70.1	78.9	89.0	100.6	114.3	131.7	155.7	186.3	223.5
15	150.8	76.7	52.7	41.4	35.3	31.9	30.2	29.8	30.3	31.6	33.7	36.8	40.6	45.3	50.8	57.1	64.4	72.9	81.5	91.5	103.0	116.6	133.9	157.8	188.3	225.5
20	200.8	101.7	69.4	53.9	45.3	40.2	37.4	36.0	35.8	36.6	38.3	40.9	44.5	48.9	54.1	60.2	67.4	75.7	84.1	94.0	105.4	118.9	136.1	159.9	190.3	227.5
25	250.8	126.7	85.7	66.4	55.3	48.6	44.5	42.3	41.4	41.6	42.8	45.1	48.3	52.5	57.5	63.3	70.3	78.5	86.7	96.5	107.8	121.9	138.3	161.9	192.3	229.5
30	-----	151.7	102.7	78.9	65.3	56.9	51.7	48.5	46.9	46.6	47.3	49.3	52.1	56.0	60.8	66.4	73.2	81.2	89.3	99.0	110.1	123.4	140.4	164.0	194.3	231.5
35	-----	176.7	119.4	91.4	75.3	65.2	58.8	54.8	52.5	51.6	51.9	53.3	56.0	59.6	64.1	69.5	76.2	84.0	91.9	101.5	112.5	125.7	142.6	166.1	196.3	233.5
40	-----	201.7	135.7	103.9	85.3	73.6	65.9	61.0	58.0	56.6	56.4	57.5	59.8	63.2	67.4	72.6	79.1	86.8	94.5	104.0	114.9	128.0	144.8	168.2	198.3	235.5
45	-----	226.7	152.7	116.4	95.3	81.9	73.1	67.3	63.6	61.6	61.0	61.6	63.7	66.7	70.8	75.9	82.1	89.6	97.1	106.5	117.3	130.2	147.0	170.3	200.3	237.5
50	-----	251.7	169.4	128.9	105.3	90.2	80.2	73.5	69.1	66.6	65.5	65.8	67.5	70.3	74.1	79.0	85.0	92.4	99.7	109.0	119.7	132.6	148.9	172.4	202.3	239.5
55	-----	-----	185.7	141.4	115.3	98.6	87.4	79.8	74.7	71.6	70.0	70.0	71.3	73.9	77.4	82.1	87.9	95.2	102.3	111.5	122.0	134.9	151.1	174.5	204.3	241.4
60	-----	-----	202.7	153.9	125.3	106.9	94.5	86.0	80.2	76.6	74.6	74.1	75.2	77.4	80.8	85.2	90.8	97.9	104.9	114.0	124.4	137.2	153.2	176.6	206.3	243.4
65	-----	-----	219.4	166.4	135.3	115.2	101.7	92.3	85.8	81.6	79.1	78.3	79.0	81.0	84.1	88.3	93.8	100.7	107.5	116.5	126.8	139.4	155.4	178.8	208.3	245.4
70	-----	-----	235.7	178.9	145.3	123.6	108.8	98.5	91.4	86.6	83.7	82.4	82.9	84.6	87.4	91.4	96.8	103.5	110.1	119.0	129.2	141.7	157.6	180.8	210.3	247.4
75	-----	-----	-----	191.4	155.3	131.9	116.0	104.8	96.9	91.6	88.2	86.6	86.7	88.2	90.8	94.5	99.7	106.3	112.7	121.5	131.6	145.0	159.8	182.9	212.3	249.4
80	-----	-----	-----	203.9	165.3	140.2	123.1	111.0	102.4	96.6	92.7	90.8	90.5	91.7	94.1	97.6	102.7	109.1	115.3	124.0	134.0	147.3	161.9	185.0	214.3	251.4
85	-----	-----	-----	216.4	175.3	148.6	130.3	117.3	107.9	101.6	97.3	94.9	94.4	95.3	97.4	100.7	105.5	111.8	117.9	126.5	136.4	149.5	164.1	187.1	216.3	253.4
90	-----	-----	-----	228.9	185.3	156.9	137.4	123.5	113.6	106.6	101.8	99.1	98.2	98.9	100.7	103.8	108.5	114.6	120.5	129.0	138.8	151.8	166.3	189.2	218.3	255.4
95	-----	-----	-----	241.4	195.3	165.2	144.6	129.8	119.0	111.6	106.4	103.2	102.1	102.4	104.1	106.9	111.5	117.4	123.1	131.5	141.1	154.1	168.4	191.3	220.3	257.4
100	-----	-----	-----	253.9	205.3	173.6	151.7	136.0	124.6	116.6	110.9	107.4	105.8	105.9	107.4	110.0	114.4	120.2	125.7	134.0	143.5	156.4	170.6	193.4	224.3	259.4
110	-----	-----	-----	-----	225.3	190.2	166.0	148.5	135.7	126.6	120.0	115.7	113.5	113.0	114.1	116.2	120.3	125.8	131.0	139.0	148.3	161.0	175.0	197.6	228.3	263.3
120	-----	-----	-----	-----	245.3	206.9	180.3	161.0	146.8	136.6	129.1	124.0	121.2	120.2	120.7	122.4	126.2	131.4	136.3	144.0	153.1	165.6	179.4	201.8	232.3	267.3
130	-----	-----	-----	-----	265.3	223.6	194.6	173.5	157.9	146.6	138.1	132.3	128.8	127.0	127.4	128.6	132.0	137.0	141.6	149.0	157.9	170.2	183.8	206.0	236.3	271.3
140	-----	-----	-----	-----	285.3	240.2	208.8	186.0	169.0	156.6	147.2	140.7	136.5	134.5	134.0	134.8	137.9	142.5	146.9	154.0	162.7	174.7	188.2	210.1	240.3	275.3
150	-----	-----	-----	-----	305.3	256.9	223.1	198.5	180.1	166.6	156.3	149.0	144.2	141.6	140.7	141.0	143.8	148.1	152.2	159.0	167.5	179.3	192.6	214.3	244.3	279.3
160	-----	-----	-----	-----	325.3	273.6	137.4	211.0	191.2	176.6	165.4	157.3	151.9	148.7	147.4	147.2	149.7	153.7	157.4	164.0	172.2	183.9	197.0	218.5	248.3	283.2
170	-----	-----	-----	-----	345.3	290.2	251.7	223.5	202.3	186.6	174.5	165.6	159.6	155.9	154.0	153.4	155.6	159.3	162.7	169.0	177.0	186.5	201.3	222.7	252.3	287.2
180	-----	-----	-----	-----	365.3	306.9	266.0	236.0	213.4	196.6	183.5	174.0	167.2	163.0	160.7	159.6	161.4	164.8	168.0	174.0	181.8	191.0	205.7	226.9	256.3	291.2
190	-----	-----	-----	-----	385.3	323.6	280.2	248.5	224.5	206.6	192.6	182.3	174.9	170.2	167.3	165.8	167.3	170.4	173.3	179.0	186.6	195.6	210.1	231.1	260.3	295.2
200	-----	-----	-----	-----	405.3	340.2	294.5	261.0	235.6	216.6	201.7	190.6	182.6	177.3	174.0	172.0	173.3	176.0	178.6	184.0	191.4	200.2	214.5	235.3	264.3	299.2

QUADRANT ANGLE IN MILS KNOWING RANGE AND V. I. (Both in Meters.)

TARGET BELOW GUN.

Based on Experimental firing at Springfield Armory during September, 1918—U. S. Cal. .30—Model 1906—150 grain bullet.

Note: Minus angles in light print and plus angles in dark print.

V.I.	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600
1	10.	5.	3.3	2.5	2.	1.6	1.4	1.2	1.1	1.	.9	.8	.75	.7	.65	.6	.6	.55	.5	.5	.45	.45	.4	.4	.4	.4
5	49.2	23.3	14.	8.6	4.7	1.4	1.7	4.8	8.1	11.6	15.6	20.1	25.3	31.0	37.5	44.7	52.7	61.7	71.1	81.5	93.4	107.4	125.1	149.4	180.3	217.5
10	99.2	48.3	30.6	21.1	14.7	9.8	5.48	1.5	2.5	6.6	11.1	15.9	21.5	27.4	34.2	41.6	49.8	58.9	68.5	79 0	91.0	105.1	122.9	147.3	178.3	215.5
15	149.2	73.3	47.3	33.6	24.7	18.1	12.6	7.7	3.	1.6	6.6	11.7	17.7	23.8	30.9	38.5	46.9	56.1	65.9	76.5	88.6	102.8	120.7	145.2	176.3	213.5
20	199.2	98.3	64.	46.1	34.7	26.4	19.8	14.	8.6	3.4	2.1	7.5	13.9	20.2	27.6	35.4	44.0	53.3	63.3	74.0	86.2	100.5	118.5	143.1	174.3	211.5
25	-----	123.3	80.1	58.6	44.7	34.7	26.9	20.2	14.1	8.4	2.3	3.3	10.1	16.6	24.3	32.3	41.1	50.5	60.7	71.5	83.8	98.2	116.3	141.0	172.3	209.5
30	-----	148.3	97.3	71.1	54.7	43.1	34.	26.5	19.7	13.4	6.8	0.9	6.3	13.0	21.0	29.2	38.2	47.7	58.1	69.0	81.4	95.9	114.1	138.9	170.3	207.5
35	-----	173.3	114.	83.6	64.7	51.4	41.2	32.7	25.2	18.4	11.3	5.1	2.5	9.4	17.7	26.1	35.3	44.9	55.5	66.5	79.0	93.6	111.9	136.8	168.3	205.5
40	-----	198.3	130.1	96.1	74.7	59.8	48.3	39.	30.8	23.4	15.8	9.3	1.3	5.8	14.4	23.0	32.4	42.1	52.9	64.0	76.6	91.3	109.7	134.7	166.3	203.5
45	-----	-----	147.3	108.6	84.7	68.1	55.5	45.2	36.4	28.4	20.3	13.5	5.1	2.2	11.1	19.9	29.5	39.3	50.3	61.5	74.2	89.0	107.5	132.6	164.3	201.5
50	-----	-----	164.	121.1	94.7	76.4	62.6	51.5	41.9	33.4	24.7	17.7	8.9	1.4	7.8	16.8	26.6	36.5	47.7	59.0	71.8	86.7	105.3	130.5	162.3	199.5
55	-----	-----	180.1	133.6	104.7	84.8	69.8	57.7	47.5	38.4	29.2	2.19	12.7	5.0	4.5	13.7	23.7	33.7	45.1	56.5	69.4	84.4	103.1	128.4	160.3	197.5
60	-----	-----	197.3	146.1	114.7	93.1	76.9	64.	53.	43.4	33.7	26.1	16.5	8.6	1.2	10.6	20.8	30.9	42.5	54.0	67.0	82.1	100.9	126.3	158.3	195.5
65	-----	-----	214.	158.6	124.7	101.4	84.	70.2	58.6	48.4	38.2	30.3	20.3	12.2	2.1	7.5	17.9	28.1	39.9	51.5	64.6	79.8	98.7	124.2	156.3	193.5
70	-----	-----	-----	171.1	134.7	109.8	91.2	76.5	64.1	53.4	42.7	34.5	24.1	15.8	5.4	4.4	15.0	25.3	37.3	49.0	62.2	77.5	96.5	122.1	154.3	191.5
75	-----	-----	-----	183.6	144.7	118.1	98.3	82.7	69.7	58.4	47.1	38.7	27.9	19.4	8.7	1.3	12.1	22.5	34.7	46.5	59.8	75.2	94.3	120.0	152.3	189.5
80	-----	-----	-----	196.1	154.7	126.4	105.5	89.	76.2	63.4	51.6	42.9	31.7	23.0	12.0	1.8	9.2	19.7	32.1	44.0	57.4	72.9	92.1	117.9	150.3	187.5
85	-----	-----	-----	208.6	164.7	134.8	112.6	95.2	80.8	68.4	56.1	47.1	35.5	26.6	15.3	4.9	6.3	16.9	29.5	41.5	55.0	70.6	89.9	115.8	148.3	185.5
90	-----	-----	-----	221.1	174.7	143.1	119.8	101.5	86.4	73.4	60.6	51.3	39.3	30.2	18.6	8.0	3.4	14.1	26.9	39.0	52.6	68.3	87.7	113.7	146.3	183.5
95	-----	-----	-----	233.6	184.7	151.4	126.9	107.7	91.9	78.4	65.1	55.5	43.1	33.8	21.9	11.1	0.5	11.3	24.3	36.5	50.2	66.0	85.5	111.6	144.3	181.5
100	-----	-----	-----	246.1	194.7	159.8	134.	114.	97.5	83.4	69.5	59.7	46.9	37.4	25.2	14.2	2.4	8.5	21.7	34.0	47.8	63.7	83.3	109.5	142.3	179.5
110	-----	-----	-----	271.1	214.7	176.5	148.3	126.5	108.6	93.4	78.0	68.1	54.5	44.6	31.8	20.4	8.2	2.9	16.5	29.0	43.0	59.1	78.9	105.3	138.3	175.5
120	-----	-----	-----	296.1	234.7	193.1	162.5	139.	119.7	103.4	87.0	76.5	62.1	51.8	38.4	26.6	14.0	2.7	11.3	24.0	38.2	54.7	74.5	101.1	134.3	171.5
130	-----	-----	-----	321.1	254.7	209.8	176.8	151.5	130.8	113.4	96.0	84.9	69.7	59.0	45.0	32.8	19.8	8.3	6.1	19.0	33.4	50.1	70.1	96.9	130.3	167.5
140	-----	-----	-----	346.1	274.7	226.4	191.1	164.	141.9	123.4	105.0	93.3	77.3	66.2	51.6	39.0	25.6	13.9	.9	14.0	28.6	45.5	65.7	92.7	126.3	163.5
150	-----	-----	-----	371.1	294.7	243.1	205.4	176.5	153.	133.4	114.0	101.7	84.9	73.4	58.2	45.2	31.4	19.5	4.3	9.0	23.8	40.8	61.3	88.5	122.3	159.5
160	-----	-----	-----	396.1	314.7	259.8	219.7	189.	164.	143.4	123.0	106.1	92.5	80.6	64.8	51.4	37.2	25.1	9.5	4.0	19.0	36.2	56.9	84.3	118.3	155.5
170	-----	-----	-----	441.1	334.7	276.4	234.	201.5	175.	153.4	132.0	110.5	98.1	87.8	71.4	57.6	43.0	30.7	14.7	1.0	14.2	31.6	52.5	80.1	114.3	151.5
180	-----	-----	-----	446.1	354.7	293.1	248.3	214.	186.	163.4	141.0	114.9	105.7	95.0	78.0	63.8	48.8	36.3	19.9	6.0	9.4	27.0	48.1	75.9	110.3	147.5
190	-----	-----	-----	471.1	374.7	309.7	252.5	226.5	197.5	173.4	150.0	119.3	113.3	102.2	84.6	70.0	54.6	41.9	25.1	11.0	4.6	22.4	43.7	71.7	106.3	143.5
200	-----	-----	-----	496.0	394.7	326.3	276.7	239.0	208.0	183.4	159.0	123.7	120.9	109.4	91.2	76.2	60.4	47.5	30.3	16.0	0.2	17.7	39.3	67.5	102.3	139.5

Lowest Shot	1.4	1.7	2.0	2.3	2.6	2.8	3.2	3.6	4.2	5.0	5.6	6.6	7.7	8.8	10.4	12.4
Clearance	10	11	13	15	17	20	23	27	32	37	45	54	64	75	87	100

ORDINATES OF NEGATIVE QUADRANT ELEVATION

Meters

Q. E. Mils.	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200
— 1.	.5	.6	.715	.8	.9	1.	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.95	2.	2.1	2.2
— 5	.5	7.25	9.7	12.8	16.9	21.6	27.5	34.5	43.	52.5	63.6	76.5	91.	107.5	126.2	146.6	169.8	195.7
— 10	7.5	10.25	13.2	16.8	21.3	26.6	33.	40.5	49.4	59.5	71.2	84.5	99.5	116.4	135.8	156.6	180.4	207.
— 15	10.	13.25	16.8	20.8	25.9	31.6	38.5	46.5	55.8	66.5	78.7	92.5	108.	125.4	145.2	166.6	191.	218.7
— 20	12.5	16.25	20.3	24.8	30.3	36.6	44.	52.5	62.4	73.5	86.2	100.5	116.5	134.3	154.6	176.6	201.4	230.
— 25	15.	19.25	23.8	28.8	34.8	41.6	49.5	58.5	68.8	80.5	93.7	108.5	125.	143.3	164.2	186.6	211.8	241.7
— 30	17.5	22.25	27.3	32.8	39.3	46.7	55.	64.5	75.4	87.5	101.2	116.5	133.5	152.3	173.6	196.6	222.2	253.
— 35	20.	25.25	30.8	36.8	43.8	51.6	60.5	70.5	81.8	94.5	108.7	124.5	142.	161.4	183.	206.6	232.7	264.7
— 40	22.5	28.25	34.3	40.8	48.3	56.6	66.	76.5	88.4	101.5	116.2	132.5	150.5	170.4	192.6	216.6	243.1	276.
— 45	25.	31.25	37.8	44.8	52.8	61.6	71.5	82.5	94.8	108.5	123.7	140.5	159.	179.3	201.2	226.6	253.5	287.7
— 50	27.5	34.25	41.3	48.8	57.3	66.6	77.	88.5	101.4	115.5	131.2	148.5	167.5	188.3	210.6	236.6	264.	299.
— 55	30.	37.25	44.8	52.8	61.8	71.6	82.5	94.5	107.8	122.5	138.7	156.5	176.	197.3	219.6	246.6	274.4	310.7
— 60	32.5	40.25	48.3	56.8	66.3	76.6	88.	100.5	114.4	129.5	146.2	164.5	184.5	206.2	228.2	256.6	284.8	322.
— 65	35.	43.25	51.8	60.8	70.9	81.6	93.5	106.5	120.8	136.5	153.7	172.5	193.	215.4	237.6	266.6	295.2	333.7
— 70	37.5	46.25	55.3	64.8	75.3	86.6	99.	112.5	127.4	143.5	161.2	180.5	210.5	224.3	246.6	276.6	305.7	345.
— 75	40.	49.25	58.8	68.8	79.8	91.6	104.5	118.5	133.8	150.5	168.7	188.5	210.	233.3	255.2			
— 80	42.5	52.25	62.3	72.8	84.3	96.6	110 .	124.5	140.4	157.5	176.2	196.5	218.5					
— 85	45.	55.25	65.7	76.8	88.8	101.6	115.5	130.5	146.8	164.5	183.7	205.5	227.					
— 90	47.5	58.25	69.2	80.8	93.3	106.6	121.	136.5	153.4	171.5	191.2	212.5	235.5					
— 95	50.	61.25	72.7	84.8	97.8	111.6	126.5	142.5	159.8	178.5	198.7							
—100	52.5	64.25	76.2	88.8	102.3	116.6	132.	148.5	166.4	185.5	206.2							
—105	55.	67.5	79.7	92.8	106.8	121.6	137.5	154.5	172.8	192.5	213.7							
—110	57.5	70.25	83.2	96.8	111.3	126.6	143.	160.5										
—115	60.	73.25	86.7	100.8	115.8	131.6	148.5	166.5										
—120	62.5	76.25	90.2	104.8	120.3	136.6	154.	172.5										
—125	65.	79.25	93.7	108.8	124.8	141.6	159.5	178.5										
—130	67.5	82.25	97.2	112.8	129.3	146.6	165.	184.5										
—135	70.	85.25	100.7	116.8	133.8	151.6	170.5	190.5										
—140	72.5	88.25	104.2	120.8	138.3	156.6	176.	196.5										
—145	75.	91.25	107.7	124.8	142.8	161.6	181.5	202.5										
—150	77.5	94.25	111.2	128.8	147.3	166.6	187.	208.5										

Note: 1. This table gives, at any distance in meters from the gun, the height **in meters** of the center shot of the cone below a horizontal plane passing through gun position. It is for use when determining clearance over our own troops' heads in indirect overhead fire.

2. The figures inline just below distances correspond to a Quadrant Elevation of −1 mil and are used for determining height for a Quadrant Elevation not a multiple of 5.

Example: Quadrant Elevation—63 mils; range 1300 meters. Height of trajectory 114.4 + 1.3 meters for each mil added above 60 mils—114.4 + (3x1.3)—118.3 meters. (Depth center shot below gun.)

MASK CLEARANCES

*Mask Distance	Required Clearance	Corresponding Range	*Mask Distance	Required Clearance	Corresponding Range
Meters	Mils	Meters	Mils	Mils	Meters
100	2.58	356	1200	2.91	1271
200	2.58	427	1300	3.15	1379
300	2.58	498	1400	3.47	1596
400	2.58	574	1500	3.81	1625
500	2.58	651	1600	4.20	1740
600	2.58	730	1700	4.65	1861
700	2.58	815	1800	5.06	2011
800	2.58	899	1900	5.53	2124
900	2.62	987	2000	6.27	2235
1000	2.68	1065	2100	7.28	2470
1100	2.78	1168	2200	8.93	2518

Mask distance is the distance in meters from the gun to the highest point of the mask.

The **actual** clearance is the number of mils by which the quadrant elevation required to strike the target exceeds the quadrant elevation required to strike the top of the mask.

That the mask may be cleared—

1. The **actual** clearance must equal or exceed the "required clearance" as given in the table above, or,
2. The gun being laid properly on the target, the line of aim must clear the mask when the sight is set at the "corresponding range" given in the table above.

CORRECTED TABLE OF SAFETY ANGLES, TO REPLACE ORIGINAL TABLE FURNISHED IN MIMEOGRAPHED FORM WHICH SHOULD BE DESTROYED

SAFETY ANGLES

*Troop Distance	Required Safety Angle	Corresponding Range	*Troop Distance	Required Safety Angle	Corresponding Range
Meters	Mils	Meters	Meters	Mils	Meters
100	80.19	1971	1100	24.66	1557
200	41.65	1536	1200	27.20	1647
300	29.15	1350	1300	30.39	1744
400	23.30	1261	1400	33.92	1845
500	20.22	1225	1500	38.07	1950
600	18.57	1224	1600	42.69	2055
700	18.92	1271	1700	49.18	2165
800	19.79	1331	1800	59.76	2283
900	20.90	1398	1900	75.86	2392
1000	22.52	1473	2000	99.17	2502

Table Corrected to Nov. 15, 1918.

* Troop distance is the distance in meters from the gun to the friendly troops over whose heads it is proposed to fire.

The **actual** safety angle is the number of mils by which the quadrant elevation required to strike the target exceeds the quadrant elevation required to strike the troops over whose heads it is purposed to fire.

In order that overhead fire may be considered safe it is necessary:

1. That the **actual** safety angle equal or exceed the "required safety angle" as given in the table above or—

2. The gun being laid properly on the target, that the line of aim clear the troops when the sight is set at the "corresponding range" given in the table above.

TABLE FOR USE IN SEARCHING REVERSE SLOPES

(All Figures in Meters)

1	2	3	4	5	6	7	8	9	10	11	12	Gun Above or Below Crest	12	11	10	9	8	7	6	5	4	3	2	1
1450	1600	1650	1700	1750	1750	1900	2000	2100	2100	2150	2200		1950	1900	1800	1750	1650	1550	1500	1350	1250	1200	1150	1100
1250	1400	1500	1550	1650	1700	1800	1850	1950	2000	2050	2100	0	2100	2050	2000	1950	1850	1800	1700	1650	1550	1500	1400	1250
1350	1450	1550	1600	1700	1750	1800	1900	1950	2000	2100	2150	10	2050	2000	1950	1900	1800	1750	1700	1600	1550	1400	1300	1200
1450	1500	1600	1700	1750	1800	1850	1950	2000	2050	2100	2150	20	2050	2000	1900	1850	1800	1700	1650	1550	1450	1350	1200	1100
1500	1600	1650	1750	1800	1850	1900	1950	2050	2050	2150	2200	30	2000	1950	1900	1850	1750	1650	1600	1500	1400	1250	1150	1000
1600	1650	1700	1750	1800	1900	1950	2000	2050	2100	2150	2200	40	2000	1950	1850	1800	1700	1600	1550	1450	1300	1200	1050	
1650	1700	1750	1800	1850	1900	2000	2050	2100	2150	2200	2250	50	2000	1900	1850	1750	1650	1600	1500	1350	1250	1100		
1700	1750	1800	1850	1900	1950	2000	2050	2100	2150	2200	2250	60	1950	1850	1800	1700	1650	1550	1450	1300	1200	1000		
1750	1800	1850	1900	1950	2000	2050	2100	2150	2200	2250	2300	70	1900	1850	1750	1700	1600	1500	1400	1250	1100			
1800	1850	1900	1950	2000	2000	2100	2150	2150	2200	2250	2300	80	1900	1800	1700	1650	1550	1450	1300	1200	1000			
1900	1900	1950	2000	2000	2050	2100	2150	2200	2250	2300	2300	90	1850	1750	1700	1600	1500	1400	1250	1100				
1950	1950	2000	2000	2050	2100	2150	2200	2200	2250	2300	2350	100	1800	1750	1650	1550	1450	1300	1200	1000				
2000	2000	2000	2050	2100	2150	2150	2200	2250	2300	2350	2350	110	1800	1700	1600	1500	1400	1250	1100					
2050	2000	2050	2100	2100	2150	2200	2250	2250	2300	2350	2400	120	1750	1650	1550	1450	1350	1200	1050					
2050	2050	2100	2150	2150	2200	2200	2250	2300	2350	2350	2400	130	1700	1600	1500	1400	1300	1100						
2100	2100	2150	2150	2200	2200	2250	2300	2300	2350	2400	2450	140	1700	1600	1450	1350	1200	1050						
2150	2150	2200	2200	2200	2250	2250	2300	2350	2400	2400	2450	150	1650	1550	1400	1300	1150	1000						
2200	2200	2200	2250	2250	2300	2300	2350	2350	2400	2450	2450	160	1600	1500	1400	1250	1100							
2250	2200	2250	2250	2300	2300	2300	2350	2400	2400	2450	2500	170	1550	1450	1350	1200	1000							
2300	2250	2250	2300	2300	2350	2350	2400	2400	2450	2450	2500	180	1500	1400	1300	1100								
2350	2300	2300	2300	2350	2350	2400	2400	2450	2450	2500	2550	190	1450	1350	1250	1050								
2350	2300	2300	2350	2350	2400	2400	2450	2450	2500	2500	2550	200	1400	1300	1200	1000								

Gun Below Crest **Gun Above Crest**

For use of this table see searching reverse slopes in indirect fire.

ALLOWANCE TABLE FOR ATMOSPHERIC CONDITIONS—Corrections in Mils.

ACTUAL RANGE IN METERS		1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
Lateral Winds	10 mile	3.	3.4	3.8	4.2	4.6	5.	5.4	5.8	6.2	6.6	7.	7.2	7.4	7.6	7.8	8.	9.6	11.2	12.8	14.4	16.
(For Head and Rear Winds take one-half. Add for Head Winds, Deduct for Rear Wind.)	20 mile	6.	6.8	7.6	8.4	9.2	10.	10.8	11.6	12.4	13.2	14.	14.4	14.8	15.2	15.6	16.	19.2	22.4	25.6	28.8	32.
	30 mile	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	20.8	21.6	22.4	23.2	24.	28.8	33.6	38.4	43.2	48.
Temperature	10 deg. F. 5.55 deg. C.	1.	1.2	1.4	1.6	1.8	2.	2.2	2.4	2.6	2.8	3.	3.2	3.4	3.6	3.8	4.	4.2	4.4	4.6	4.8	5.
Normal—	20 deg. F. 11.11 deg. C.	2.	2.4	2.8	3.2	3.6	4.	4.4	4.8	5.2	5.6	6.	6.4	6.8	7.2	7.6	8.	8.4	8.8	9.2	9.6	10.
F=60 deg. C=15.56 deg.	30 deg. F. 16.67 deg. C.	4.	4.4	4.8	5.2	5.6	6.	6.4	6.8	7.2	7.6	8.	8.4	8.8	9.2	9.6	10.	10.4	10.8	11.2	11.6	12.
Above Normal Deduct.	40 deg. F. 22.22 deg. C.	8.	8.4	8.8	9.2	9.6	10.	10.4	10.8	11.2	11.6	12.	12.4	12.8	13.2	13.6	14.	14.4	14.8	15.2	15.6	16.
Below Normal Add.	50 deg. F. 27.27 deg. C.	10.	10.4	10.8	11.2	11.6	12.	12.4	12.8	13.2	13.6	14.	14.4	14.8	15.2	15.6	16.	16.4	16.8	17.6	17.6	18.
Barometer	.5 inch. 1.27 cm.	1.	1.2	1.4	1.6	1.8	2.	2.2	2.4	2.6	2.8	3.	3.2	3.4	3.6	3.8	4.	4.2	4.4	4.6	4.8	5.
Normal—	1.0 inch. 2.54 cm.	2.	2.2	2.4	2.6	2.8	3.	3.2	3.4	3.6	3.8	4.	4.4	4.8	5.2	5.6	6.	6.4	6.8	7.2	7.6	8.
30 inches, 72.6 cm.	1.5 inch. 3.81 cm.	4.	4.4	4.8	5.2	5.6	6.	6.4	6.8	7.2	7.6	8.	8.4	8.8	9.2	9.6	10.	10.4	10.8	11.2	11.6	12.
Above Normal Add, Below Normal Deduct.	2.0 inch. 5.08 cm.	6.	6.4	6.8	7.2	7.6	8.	8.8	9.6	10.4	11.2	12.	12.6	13.2	13.8	14.4	15.	15.6	16.2	16.8	17.4	18.

Example: Range 2,500 meters, Angle of Departure 111.8 mils, Rear Wind 20 miles, 80° F., 31 inch Barometer.
In 2,500 meter column find under 20 mile wind 16 mils. ½ of this deducted from 111.8mils=103.8 mils.
80° F. is 20° above Normal and 8 mils are deducted from 103.8 mils, leaving 95.8 mils. 31 inch Barometer pressure is 1 inch above Normal, adding 6 mils to elevation. This brings the final elevation to 101.8 mils, corresponding to an elevation of 2,400 meters.

APPROXIMATE METHODS

Allowances for Atmospheric Influences

I

More Elevation	Less Elevation.
Cold (40° Fahrenheit or less). Strong head wind. Extreme dryness. Bright light.	Heat (80° Fahrenheit or more). Strong rear wind. Rain. Over 1000 meters above sea level. Very poor light. Firing up or down hill (may be neglected when angle of site to target does not exceed 130 mils.

Allowances in Meters of Range

II

Range	One Factor (Meters)	Two Factors (Meters)
1000 Meters		50
1500 Meters	50	100
2000 Meters	100	150

NOTES

(a) Each of the atmospheric conditions in Table I is assumed to constitute one factor; the necessary amount of more or less elevation required to counteract a factor at each range is given in Table II.

(b) Factors affecting elevation in opposite directions will naturally cancel each other.

Examples:

1. **Factor:** Range 1500 meters: —Bright Light—Sight Setting: 1550 Meters.
2. **Factors:** Range 2000 Meters: —Rain—Strong Rear Wind—Sight Setting: 1850 Meters.

This table is for rough approximation only.

METRIC SYSTEM
(Compared with English.)
LONG MEASURE

	Meters	Inches	Feet	Yards	Miles
Millimeter	.001	.03937	.00328	.00109	——
Centimeter	.01	.3937	.0328	.0109	——
Decimeter	.1	3.937	.328	.10936	.00006
Meter*	1.	39.37011	3.2808	1.09361	.00062
Decameter	10.	——	32.808	10.936	.00621
Hectometer	100.	——	328.	109.36	.06214
Kilometer	1,000.	——	3280.8	1093.6	.62137
Myriameter	10,000.	——	——	——	6.21372

*1 meter—1.0936143 yard.

LINEAR MEASURES

Inch	—	.0254000 meters	39.370113
Foot	—	.3047997 "	3.280843
Yard	—	.9143992 "	1.093614
Pole	—	5.0292 "	.198839
Chain	—	20.1168 "	.0497097
Furlong	—	201.1678 "	.0049710
Mile	—	1609.3426 "	.00062137

Mils and Minutes Equivalent

Mils	Mins.	Mils	Mins.	Mils	Mins.
1	3	27	92	54	185
2	6	28	96	55	188
3	10	29	99	56	192
4	13	30	103	57	195
5	17	31	106	58	199
6	20	32	109	59	202
7	24	33	113	60	206
8	27	34	116	61	209
9	30	35	120	62	212
10	34	36	123	63	216
11	37	37	127	64	219
12	41	38	130	65	223
13	44	39	133	66	226
14	48	40	137	67	230
15	51	41	140	68	233
16	54	42	144	69	236
17	58	43	147	70	240
18	61	44	151	71	243
19	65	45	154	72	246
20	68	46	157	73	250
21	72	47	161	74	254
22	75	48	164	75	257
23	78	49	168	76	260
24	82	50	171	77	264
25	85	51	175	78	267
26	89	52	178	79	271
		53	181	80	274

A combination of the above will give results for Mils above 80.

A Mil is 3 Mins. 26.2 Secs.

There are 6,400 Mils in a circle.

A Mil subtends 1 inch at 100 inches.

A Mil subtends 1 foot at 100 feet.

A Mil subtends 1 yard at 1000 yards.

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